

POLLEN SEDIMENTATION IN RELATION
TO THE QUATERNARY VEGETATION HISTORY
OF THE SNOWY MOUNTAINS OF NEW SOUTH WALES

by

J.I. RAINE

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ABSTRACT

Pollen influx into Blue Lake in the alpine area of the Snowy Mountains of southeastern Australia was measured by pollen traps, snow and stream water samples and lake sediment traps. Pollen deposition in a nearby forested area was also investigated. Pollen deposition rates were calculated for a pair of cores from the lake, yielding a record over the last 13000 years, supplementary material from the nearby Twynam Cirque extending the sequence to 20000 years B.P. Possible causes of distortions in the pollen diagrams arising from differential pollen deposition and sediment redeposition are regarded as not significant.

Vegetation was absent from the area before 17000 B.P., when snowpatch and feldmark communities appeared. Further amelioration occurred between 13000 and 17000 years B.P., after which conditions appeared to remain the same until 8700 years B.P., when a great increase in total pollen deposition rate was associated with rise of the treeline to its present position, and further development of the alpine vegetation. Forest of moister aspect than the present day prevailed from 7700 to 6500 years B.P., after which relative wetness declined to a minimum at about 3800 years B.P. Slight increase in available moisture has occurred since 1500 years B.P.

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J.I. Raine, 10 July 2016

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PREFACE

This study arose from my desire to learn something of Quaternary pollen analysis and the problems in its application to the study of vegetation and climatic history. By training a geologist, I hope to return to more geological pastures at least partly purged of wild fancy by a dose of Lyell's dictum that 'the present is the key to the past'. The thesis displays a preoccupation with technical and taxonomic problems which I feel justified in view of the paucity of available information in Australia in such basic fields as pollen morphology, and by my being a beginner as well as a local pioneer.

The completion of this work is largely due to the encouragement and patience of my supervisor, Professor D. Walker, whose help I gratefully acknowledge. Other members of the Department of Biogeography and Geomorphology who helped in various ways in the laboratory and field include Mrs. M. Arney, Mr. J.R. Caldwell, Dr. J.M. Bowler, Mr. K. Fitchett, Mrs. J.C. Guppy, Mr. W. Hocking, Mr. D. James, Dr. J.N. Jennings, Miss C. Joyce, Mr. R.A. McDonell, Mrs. D. Moss, Mr. J. Neale, Mrs. M. Ramsay, Mrs. H. Salzmann, Dr. G. Singh and Mrs. C. Thompson.

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I have benefited greatly from the work and advice of Dr. A.B. Costin, of the C.S.I.R.O., Canberra. Other C.S.I.R.O. people I wish to thank include Mr. D. Wimbush, Mr. W. Litchfield, Mr. P. Milne, Dr. P. Walker, and the staff of the Herbarium Australiense, particularly Mr. M. Gray, who helped with plant identification and provided reference pollen material.

The thesis was typed by Mrs. J. McKendry, and figures produced by Mr. J. Heywood, of the Department of Human Geography. Financial support was provided initially by an Australian National University Postgraduate Scholarship, and later by my father-in-law, Mr. F.J. Kornfeld.

Last but not least, I thank my wife for her unfailing love and encouragement, and her very considerable aid in fieldwork, proof-reading and drafting nearly all the figures.

Canberra

September 1974

CHAPTER 1

INTRODUCTION

Origins of the Australian Flora

The origin of the Australian flora has been a question of much discussion and speculation over the years. In the present-day flora biogeographers have distinguished several elements on the basis of affinity with the floras of other regions (e.g. Hooker, 1860; Bentham, 1878; Burbidge, 1960). These include an Australian, or endemic element, differentiated into south-western and south-eastern subelements, an Antarctic, with South African, South American and SubAntarctic Island affinities, a Palaeotropic, with south-east Asian affinities, and a Cosmopolitan element. The distribution of these elements largely reflects the ecology of their supposed source areas. Thus the Palaeotropic or Indo-Malayan element is best represented in the tropical rainforests of northern Queensland, while the Antarctic element has its greatest representation in the cool temperate climate of Tasmania.

Interpretation of the arrival and distribution of these floristic elements in terms of climatic and biological factors has been limited by a lack of knowledge of the past configuration of land and sea and of the past distribution of the elements themselves. New evidence on continental drift, provided largely by palaeomagnetic studies, has prompted recent attempts at reconstruction of the palaeobotany and palaeozoology of the Southern Hemisphere (Jardine and McKenzie, 1972; Raven and Axelrod, 1972), but basic palaeobotanic data is still greatly lacking. A general outline can however be drawn, mainly from the many papers of Cookson (e.g. 1957), and from Harris (1965), Churchill (1973), Stover and Evans (1973), Dettmann (1973) and Martin (1973).

Angiosperms appear in eastern Australia in the late middle Albian, apparently later than in parts of the northern hemisphere, suggesting migration into, rather than evolution within, Australia. Albian and Cenomanian floras were fairly uniform, but geographic differentiation had become evident between floras in high and low palaeolatitudes by the Turonian. In the Eocene representatives of many modern families had made their appearance, including Podocarpaceae, Araucariaceae,

Araliaceae, Myrsinaceae, Proteaceae, Winteraceae, Atherosper-
maceae, Lauraceae, Malvaceae, Loranthaceae, Sapindaceae,
Cunoniaceae, Myrtaceae, Olacaceae, Rhizophoraceae, Casuarinaceae
and Fagaceae (including Nothofagus), and thus components of
the Australian, Antarctic and Palaeotropic floristic elements.

Climate in the Eocene appears to have been tropical (Churchill, 1973), and pollen and spore assemblages are dominated by Proteaceae and Nothofagus. In the Oligocene, there is an increase in the importance of gymnosperms, suggesting a cooler climate (Burbidge, 1960). Martin (1973) has demonstrated an alternation of pollen assemblages in sediments of probable Miocene to Pliocene age in the Murray Basin, in which Nothofagus and gymnosperm-rich phases intervene in a sequence dominated by pollen of Myrtaceae and Casuarina. Older deposits in the same area are rich in Nothofagus. It is suggested that these changes are due to the onset of climatic fluctuations in the late Pliocene. The time of final contraction of the cool temperate rain forest vegetation, suggested by the Nothofagus and gymnosperm-dominated pollen assemblages of the Tertiary, to their present restricted occurrence on the Australian mainland in montane areas of very high rainfall, is not known.

Special Problems of the Quaternary in South-eastern Australia

The contraction of rainforest from its former extent, with the extinction of much of the Tertiary flora, and expansion of sclerophyll vegetation has been mentioned. That climatic change was one of the causes of this contraction is generally suspected, but the timing and specific nature of this change in terms of precipitation and temperature have yet to be elucidated. Other problems include:

- i) The role of aboriginal man and his use of fire in the stability of sclerophyll vegetation, in which many species are fire tolerant and adapted to rapid regeneration after fire (Jacobs, 1955).
- ii) The magnitude of Quaternary climatic changes and their effect on the sclerophyll vegetation.
- iii) Whether such climatic changes were synchronous with those deduced in other parts of the world.

Previous pollen analytic and geomorphic studies having a bearing on these points are discussed in the closing chapter of this thesis.

Reasons for choice of the Snowy Mountains region for a pollen analytic study of vegetation history:

- i) There is a relative paucity of suitable sites for pollen analysis in eastern Australia. The studies of Churchill (1960b) and Hope (1968) on coastal lagoon sites showed these to be dominated by changes in local vegetation associated with the Flandrian rise in sea level. Inland lakes are mainly ephemeral and pollen preservation is suspect. Permanent lakes and peat deposits are confined to the higher rainfall belt of the Great Dividing Range, including the Snowy Mountains region. Here, Costin (1972) had shown the existence of radiocarbon-datable peat deposits and sediments covering the period from 20000 years ago to present. In particular, the area includes several permanent lakes of moderate size which could be expected to yield pollen diagrams not greatly complicated by hydroseral vegetation changes (Faegri and Iversen, 1964).
- ii) The area is one of great topographical and climatological diversity, with vegetation from alpine herbfield to wet sclerophyll forest, which suggested that past climatic changes, indicated by the occurrence of former glacial and widespread periglacial features, would be reflected in the pollen records. Wood of Nothofagus, now absent from the region, in periglacial deposits dated at 35000 years before present (Jennings and Caine, 1968) lent support to this idea.
- iii) The flora and vegetation of the area are relatively well known, from the work of Costin (1954), Morland (1959) and McVean (1969).
- iv) Since it was desired to conduct a study of modern pollen sedimentation in connection with the vegetation history study a site near to Canberra was an advantage, in enabling regular visits and laboratory support.

Scope and Plan of the Study

Of the four possible lake sites in the alpine area, Blue Lake was chosen since as the deepest and largest lake its sediments might have been less susceptible to disturbance and have been deposited at a steady rate. In addition, cores obtained by Costin (Costin, 1972) had yielded radiocarbon dates of over 5000 years before present and

indicated the presence of older material. Since it was felt that the regional pollen record of the other lake sites would be similar, it was decided to concentrate on as full an interpretation of the Blue Lake pollen record as possible, particularly since time allowed only a reconnaissance study. The pollen record was later extended by examination of older dated sediments from Twynam Cirque. An attempt was also made to recover pollen from buried humic soils dated at about 30000 years before present (Costin and Polach, 1971), but this proved unsuccessful.

Classical pollen analysis proceeded by the comparison of relative frequencies of fossil pollen types in the peat or sediment with the relative frequencies observed in samples taken to represent the pollen sedimentation of modern plant communities. In this way the relative importance of these plant communities in the past could be deduced. The theoretical advantages of pollen studies in which pollen deposition per unit area of, for example, bog surface per year was known were long appreciated, but depended on accurate measurement of sedimentation rates, not generally possible before radiocarbon dating became readily available. Such measures free the interpreter of the problem that increase in relative frequency of one pollen type must necessarily decrease the frequency of other pollen types, whether the actual vegetation producing these types decreased in importance or not. One of the first successful demonstrations of this technique was that of Davis and Deevey (1964), who showed that an apparent replacement of nonarboreal vegetation by forest in the late-glacial period of the northeastern United States, as indicated by a relative pollen frequency (percentage) diagram, was misleading. The pollen deposition rate figures, calculated by dividing pollen numbers per cubic centimetre of sediment by the number of years needed to deposit 1 cm thickness of sediment, showed that deposition of sedge pollen continued unabated, while that of grass pollen actually increased along with the tree pollen deposition increase. The relative frequencies of other important taxa were also misleading.

The application of such a study to the Blue Lake situation, where a similar transition from late-glacial to post-glacial vegetation was likely, was thought desirable. Results of this work are described in Chapter 3.

Later studies by Davis (1968) showed that considerable redeposition of pollen and lake sediment can take place. Differential deposition and redeposition of pollen of different taxa was also a possibility. For example, Hopkins (1950) had shown that some pollen types floated on the water surface, allowing considerable wind transport to occur before deposition in lake sediment.

Modern pollen samples for comparison with fossil pollen spectra have generally been taken from soil surface litter or moss below the plant canopy. This is appropriate for sedimentary basins where the vegetation has actually overtopped the pollen analysis site, but is not so suitable where the site is more open, or for studies of regional vegetation, since Tauber (1965) and others have emphasised the composite nature of the pollen influx to a site. Tauber recognized three main components of aerial pollen deposition: a trunk space component, blown through forest below the canopy; a canopy component present above the vegetation; and a rainout component derived from higher in the atmosphere by impaction on raindrops. These components would be successively more regional in their pollen representation, and could be expected to be of varying importance in sedimentary basins of different size and morphometry.

To gauge the relative importance of these components at the Blue Lake site, and to attempt to discover differential pollen deposition or redeposition, a trapping scheme for the modern pollen sedimentation was conceived. This would attempt to gauge the absolute magnitude and relative composition of pollen influx to the lake from the air, and from influent streams, and compare this with the rate of deposition of pollen in the sediment, and loss from the lake basin by the effluent stream. By conducting the experiment as a balance or budgetary study deficiencies in technique as well as unforeseen factors in pollen deposition might be revealed.

Since the lake is ice and snow covered during the winter, the trapping study was conducted in the following manner. Aerial pollen traps, to sample canopy and rainout components of the pollen deposition, were placed around the lake and operated during the ice-free months in two years. Snow was sampled from various sites, to estimate the influx of pollen during the season when pollen trap operation was neither practical nor

appropriate, immediately before the beginning of trap operation. Sediment traps were placed in various positions in the lake. Finally, stream water samples were collected on several occasions. The choice of pollen traps, calibration, and details of pollen collection and processing procedures for these modern samples and for fossil samples are described in Chapter 2. Details of trapping and sampling periods, trap siting, and results are discussed in Chapter 4.

SOUTH-EASTERN AUSTRALIA

Geomorphology

The geology of south-eastern Australia has been most recently summarised by Brown, Campbell and Crook (1968), and that of the New South Wales portion by various authors in the publication edited by Packham (1969). The greater part of the area is of deformed and intruded lower Palaeozoic rocks of the Lachlan and Tasman Geosynclines, although in the north-western corner of the area depicted in Fig. 1.1, older (Archaean) metamorphics occur. Superimposed on these deformed rocks, which form the Eastern Highlands and Far West Uplands respectively, are sedimentary basins apparently initiated during the Permian period. Of these, the Sydney, Gippsland, Bass, and Otway Basins are more or less confined to the coastal flank of the Highlands, while the Murray Basin underlies the greater part of the western plains (approximately north and east of the 50 cm isohyet). Sedimentation in the Sydney Basin ceased in the Triassic, but continued into the Tertiary in the other basins.

In the Eastern Highlands the Great Dividing Range separates inland-flowing rivers of the Murray River system from coastal streams. The topography of the highlands is characterised by a succession of northwards-trending horsts and grabens related to Tertiary uplift (Craft, 1933). Relief is greatest in the region of Mt. Kosciusko, the highest peak in Australia (2228 m), where there is a steep descent from the Kosciusko Plateau to the Western Plains. To the north there is a more gradual transition from the Tableland via the Western Slopes. A pronounced topographic discontinuity lying 10-50 km from the coastline marks the eastern edge of the Highlands, and the western edge of the deeply dissected country of the Coastal Fall.

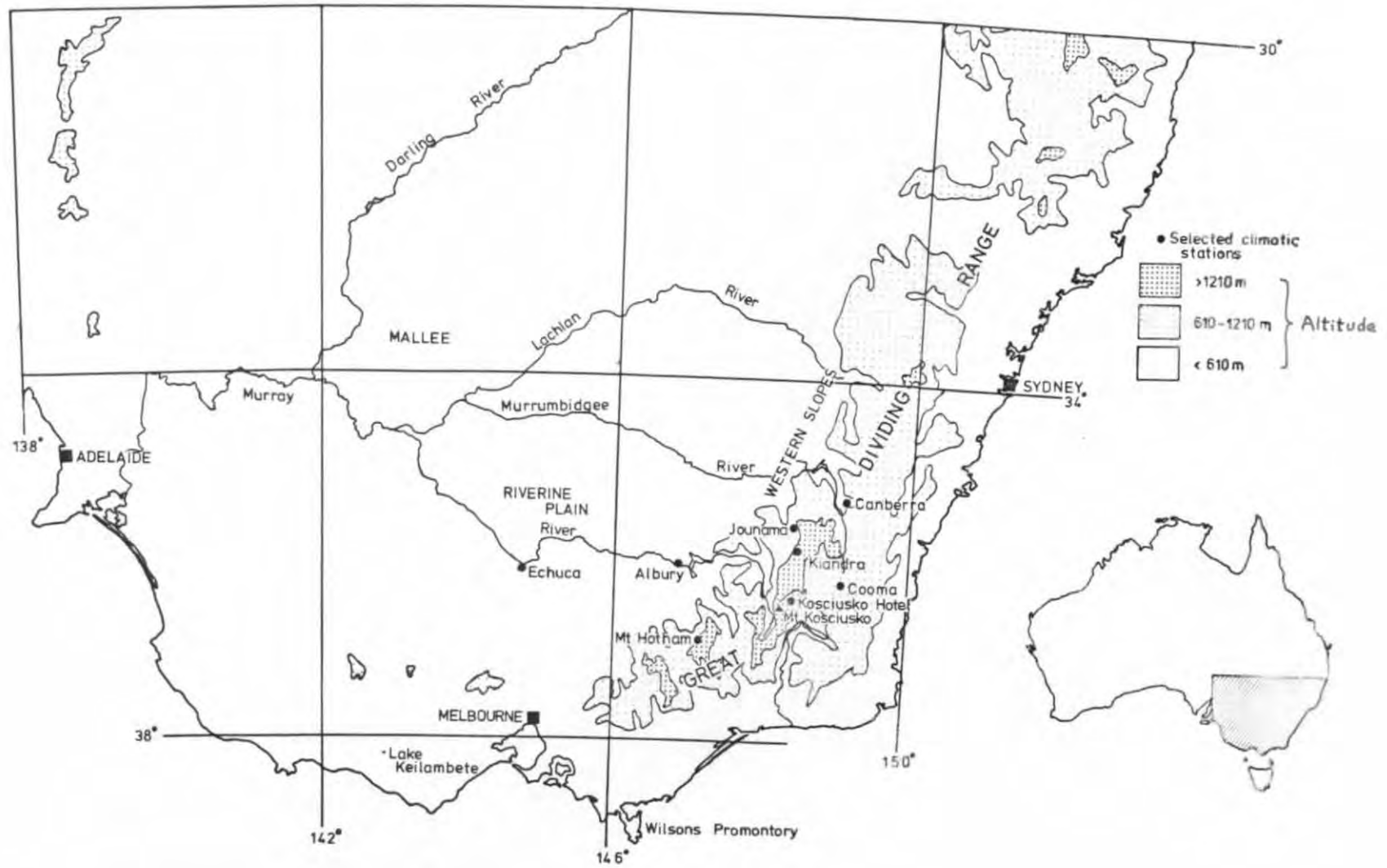


FIG. 1.1 LOCATION OF THE STUDY AREA AND PLACES MENTIONED IN THE TEXT

Post-Cretaceous physiographic history may be summarised as follows:

- i) Elevation and dissection of a Cretaceous peneplain about the close of the Eocene and early in the Oligocene during the Kiandra Epoch.
- ii) Alluviation of valleys followed by outpourings of flood basalts.
- iii) Reduction in relief, accompanied by deep weathering.
- iv) Moderate differential uplift about the close of the Miocene during the Macleay Epoch, followed by prolonged Pliocene stillstand.
- v) Repeated differential uplift, chiefly in late Pliocene or early Pleistocene (Kosciusko Epoch), initiating vigorous erosion and stream incision, and causing emergence of the previously marine embayment of the Murray Basin to form the south-western part of the Western Plains, generally known as the Mallee in distinction to the eastern Riverine Plane. Uplift preceded Pleistocene glaciation of the Kosciusko Plateau, the beginning of which, however, remains undated.
- vi) In the Highlands climatic fluctuations played a considerable role in Quaternary landform evolution (Galloway, 1969). For areas above approximately 1000m colluviation took place by frost shattering of bed-rock and solifluction of the resulting debris during colder climatic conditions. For areas below 1000m a complex sequence of periods of colluviation and alluviation alternating with periods of soil development has been established (van Dijk, 1959). Water balance studies related to high-level shorelines of Lake George, north of Canberra, imply that last glacial maximum high levels were maintained under colder and drier conditions than present (Coventry, 1973). Interfingering of colluvial rubbles and beach gravels shows that some colluviation took place here also (at approximately 700 m above sea level) during colder glacial-age climates.

In the Riverine Plain a complex system of abandoned river channels and alluvial deposits has prompted much study and speculation (see Bowler and Harford, 1966; Bowler, 1967). Within the period accessible to radiocarbon

dating, source-bordering sand dunes were extensively developed along streams dated between 20000 and 8000 years before present, but apparently not before or after this period. It is suggested that formation of these dunes required absence of the protective canopy of eucalypt forest now present along the streams, and this is substantiated by the stratigraphic distribution of fossil wood. Stream discharges appear to have been higher than present during the dune-building period.

Climate

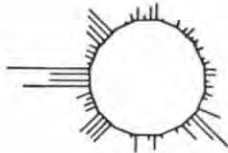
The major external control of climate in south-eastern Australia is the north to south alternation of the subtropical belt of high pressure from winter to summer. Large oval anticyclones may cover the whole of the Australian continent and part of the Southern Ocean. These travel from west to east at an average rate of 500 miles a day. Wedges of lower pressure between these anticyclones are best thought of as extensions from the equatorial belt to the north, and from the temperate low-pressure belt to the south of the continent.

In winter the axis of maximum anticyclonicity lies near 27-30°S latitude (Brookfield, 1970), and the weather pattern is typified by the passage of cold fronts associated with troughs and depressions centered to the south (Kraus, 1954). These are commonly associated with rain and frontal fogs, and snow at higher altitudes, while the passage of high pressure is usually accompanied by calm weather with sunny days and frosty nights. In summer, the belt of high pressure moves southwards, and is centered between 35° and 40°S latitude. Rainfall, especially along the east coast, is then generally due to southerly extensions of tropical low-pressure systems. In coastal areas, sea breezes, particularly during the summer, constitute an important control, and are responsible for some precipitation in the coastal ranges. Their effect is not generally felt further inland than the Great Dividing Range.

The climate of the particular area of interest to this study, the Riverine Plain to the Southern Highlands, has been described in most detail by Beadle (1948), Moore (1953), Morland (1958), Costin (1954) and McAlpine and Yapp (1969). Wind regime for four selected stations is shown in Figure 1.2a (from Department of National Development, 1953; McAlpine and

ALBURY

lat. 36° 05'S
 long. 146° 55'E
 alt. 170m

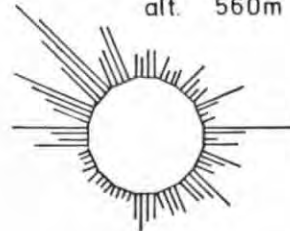


Calms/month

D	J	F	M	A	M	J	J	A	S	O	N
69	68	76	75	79	82	86	87	77	73	68	56

CANBERRA

lat. 35° 20' S
 long. 149° 10' E
 alt. 560m

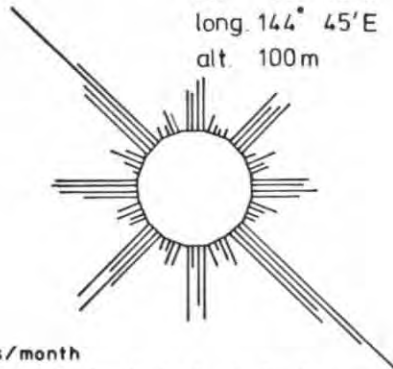


Calms/month

D	J	F	M	A	M	J	J	A	S	O	N
11	14	12	16	17	18	17	17	14	12	14	10

ECHUCA

lat. 36° 08'S
 long. 144° 45'E
 alt. 100m

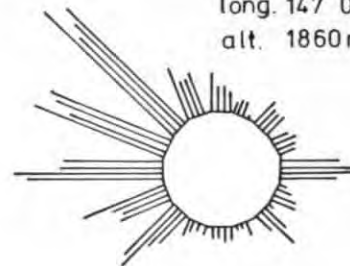


Calms/month

D	J	F	M	A	M	J	J	A	S	O	N
0	0	0	1	0	1	0	1	0	0	0	0

MT HOTHAM

lat. 36° 58' S
 long. 147° 08' E
 alt. 1860m



Calms/month

D	J	F	M	A	M	J	J	A	S	O	N
3	1	4	3	5	4	2	1	1	2	2	3

The wind-rose polygons have sides facing the sixteen points of the compass. On each side are four lines representing

- i) Seasons, reading clockwise :
 - Summer (Dec., Jan., Feb.),
 - Autumn (Mar., Apr., May),
 - Winter (June, July, Aug.),
 - Spring (Sept., Oct., Nov.)
- ii) Direction of wind (towards the centre)
- iii) Percentage frequency - proportional to length

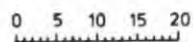


FIG. 1. 2a WIND DIRECTION AT SELECTED STATIONS (9 A.M. LOCAL TIME)

Yapp, 1969) and average monthly temperature and precipitation of typical stations in Fig. 1.2b (derived from data in Bureau of Meteorology, 1969). See also mean annual isohyets in Fig. 1.3. Brief notes on these major climatic factors follow.

i) Wind

In the western plains several wind directions are important (Echuca), associated with the passage of the pressure systems, but strengths are generally low. There is probably considerable observer bias in the Echuca data, as was found by Brookfield (1970) for other Australian wind data, but the figures for the other stations shown appear more reliable. Towards the mountains variability decreases and dominant winds blow from the west and northwest over most of the region, although southeasterly to southwesterly winds are common to the east and southeast of the highlands. Highest strength and greatest dominance of the westerly air flow is noted at the most elevated stations (e.g. Mt. Hotham).

ii) Precipitation

As with other climatic variables, this is modified locally by the orographic effect of the north-south orientation of the ranges, which lie athwart the general air stream, and by aspect and the general elevation of the area. Orographic uplift induces precipitation on the western slopes of the ranges and, by a Föhn effect, results in rain shadows to the east which are most marked where the ranges are highest. A winter rainfall regime obtains to the east of the ranges, while the coastal belt receives most of its precipitation in summer, from the incursion of moist maritime air from the Pacific. The effect of these factors can be seen in Fig. 1.2b.

Precipitation increases with increasing altitude eastwards through Echuca (57.4cm annual average rainfall), Albury (70.3cm), Jounama (129.9 cm) to Kiandra (154.1 cm) and Mt. Hotham (147.6 cm). A slight rainshadow effect is already noticeable at Kosciusko Hotel, 10 Km to the east of The Snowy Mountains (123.8 cm). At Canberra (59.2 cm) precipitation is evenly distributed through the year. At Cooma (47.9 cm), the rainshadow effect is more noticeable, and most rain falls in summer, under the influence of the maritime regime, although this is reduced by a rainshadow effect from the coastal ranges.

Winter rainfall is the most reliable, hence rainfall variability is highest in the rainshadow areas, which depend on

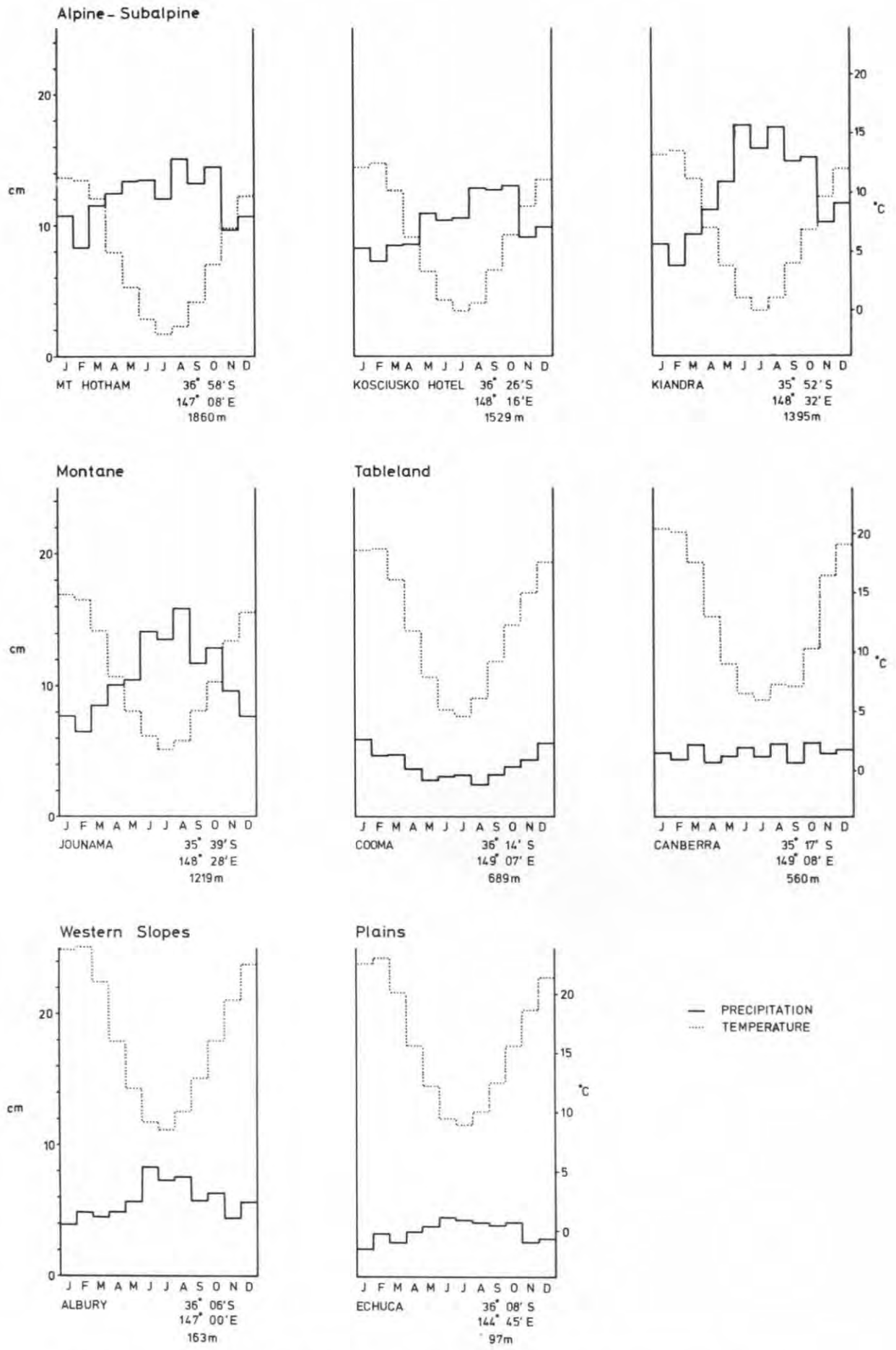


FIG. 1.2b AVERAGE MONTHLY TEMPERATURE & PRECIPITATION FOR SELECTED STATIONS

erratic convective summer storms for a large part of their precipitation. It is also high in the relatively lower rainfall areas of the western and northern part of the Western Plains. Summer drought is an oft-recurring phenomenon over the whole region.

Rainfall intensity is often high, and is highest in the region of maximum annual precipitation. Forms of precipitation recorded include rain, snow, hail, mist and dew. Most precipitation is received as rain, except at elevations above 1000 m, where snow commonly falls in winter. This does not usually remain on the ground for more than two to three weeks except above 1700 m. On exposed situations in the mountains snow lies for one to four months, but leeward snow patches may persist through the summer months. Costin (1954) notes that the number of months with a mean temperature of less than 0°C approximates to the length of snow-lie in the alpine and sub-alpine tracts, while the lower limit of the subalpine tract occurs where the mean temperature for a single month is just below this value. Hail mainly occurs during the summer and autumn months, at Canberra twice a year on the average. Mist is an important form of precipitation only above 1700 m, although also significant in certain physiographic situations at lower elevations. Heavy dews are also experienced in these situations.

iii) Temperature.

Altitude is the major determinant of mean temperature in the region, both monthly and annual. Local position in relation to topography is also important in the Highlands area, where cold air drainage into valleys at night, especially under stable anticyclonic conditions, produces 'frost pockets' which are an important factor in determining the distribution of certain plant communities and soils in the region.

Of the stations given in Fig. 1.2, Albury has the highest mean annual temperature, 16.2°C , followed by Echuca (15.9°C), Canberra (13.2°C), Cooma (11.9°C), Jounama (8.2°C), Kiandra (6.9°C), Kosciusko Hotel (6.3°C) and Mt. Hotham (4.7°C), in altitudinal sequence.

At all stations July is the coldest month, while the warmest month may be either January or February. Mean monthly temperatures range from 8.9°C at Echuca to -2.0°C at Mt. Hotham in July, and from 23.0°C to 11.1°C at these stations in

February. Mean monthly minima for the same stations are 4.6°C and -4.2°C in July and 15.6°C and 6.8°C in February. Mean monthly maxima are 13.3°C and 0.2°C in July and 30.4°C and 15.4°C in February. Diurnal range in temperature is thus greater in summer than in winter, the effect being more pronounced at higher elevations, where winter snow cover equalizes temperatures in winter while radiative gains and losses are more rapid in summer than at lower levels.

Extreme screen temperatures in summer at Canberra exceed 100°F (37.8°C) in about 25% of years, and rarely exceed this temperature above 1000 m. Screen temperatures below 0°C occur in Canberra on the average on 55 days in the years, while ground frosts occur more frequently, at Kiandra in all months.

McAlpine and Yapp (1969) state that a lapse rate of $0.55^{\circ}\text{C}/100\text{ m}$ may reasonably be assumed to apply to mean monthly temperatures in the Highlands.

Vegetation

Detailed vegetation studies have been made in the Western Plains by Beadle (1948), in the Riverine Plain by Moore (1953), in the upper Murray River region by Morland (1958) and by Costin (1954) in the Southern Highlands, or Monaro. Details of the vegetation associations recognised by these authors would be too voluminous to reproduce here. The map of vegetation formations (Figure 1.3) has been generalised from that of Williams (1955), which was largely based on the work of these authors in this region. It must be noted that this is a reconstruction of the vegetation existing before European settlement. In most areas sufficient relic stands of this vegetation occur to make this quite reliable. The description below follows that of Williams.

i) Grassland

In the map area this comprises Temperate Tussock Grassland in the rainshadow area east of Mt. Kosciusko and in the area shown as woodland near Melbourne, and Semi-Arid Tussock Grassland in part of the northwestern area shown as shrubland, within the 25 cm isohyet.

Temperate Tussock Grassland is dominated by perennial grasses up to 1 m in height, forming discrete and open tussocks isolated at their bases, but with an interlacing leaf canopy below which smaller annual and perennial herbs are present. Much of what was savannah woodland has become a disclimax tussock grassland with the advent of clearing for grazing purposes by European man. Dominant native grasses are Danthonia spp., Stipa spp., Themeda australis, and Poa spp. Introduced plants include legumes, Trifolium spp., grasses Hordeum murinum, Lolium rigidum, Bromus spp., and others, depending on management practices. Soils are usually heavy and only moderately drained.

Semi-Arid Tussock Grassland is dominated by an open cover of xeromorphic grasses of tussock form, mainly Astrebla spp. In southern New South Wales a large area is mapped as shrubland because the available evidence indicates that the present grassland is a disclimax held in its present state by grazing. This community is also associated with heavy soils with moderate to poor drainage.

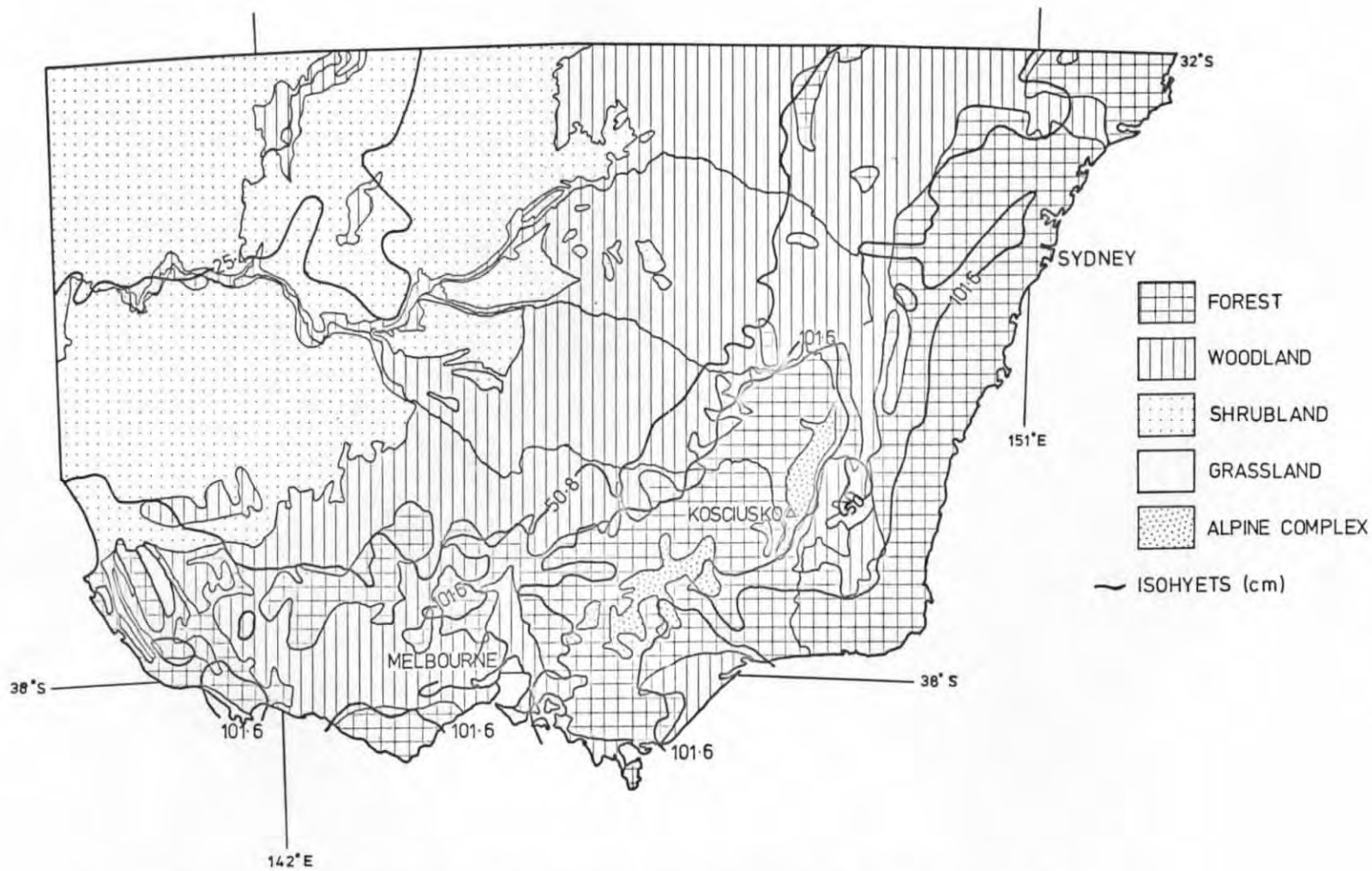


FIG. 1.3 NATIVE VEGETATION FORMATIONS OF SOUTH-EAST AUSTRALIA
(Generalised from Williams, 1955)

ii) Shrubland

In the map area this comprises mainly Shrub Steppe, and Semi-Arid Mallee, with minor areas of Sclerophyll Mallee in the southwest and Arid Scrub in the west.

Shrub Steppe is dominated by low (<50cm) shrubs with semi-succulent leaves, typically halophytes of the family Chenopodiaceae, Kochia spp. and Atriplex spp. It occurs on fairly heavy textured desert loams in areas of flat to gently undulating topography. It grades into Arid Scrub, Semi-Arid Grassland, and Semi-arid Mallee. Grazing is usually light, but in some areas has reduced the community to grassland.

Mallee is a vegetation type peculiar to Australia. It is dominated by low trees or shrubs 2-8 m high, species of Eucalyptus with many stems arising from an underground lignotuber. The umbrella-shaped canopy is continuous to very open. Sclerophyll Mallee is distinguished from Semi-Arid Mallee by the presence of a sclerophyllous shrub understorey as opposed to a more open understorey with semi-succulents (Chenopodiaceae), spiny and leafless shrubs (including Acacia) and an annual herbaceous layer. Mallee occurs on soils of poor drainage and nutrient status, in areas of higher rainfall than Shrub Steppe.

Arid Scrub is dominated by a layer of tall shrubs or low trees branching close to the ground. There are usually poorly developed subordinate strata of ephemeral shrubs and herbs. Dominants are usually non-eucalypts.

iii) Woodland

In the map area this comprises Temperate Tree Savannah, Low Shrub Woodland, Temperate Woodland, and a small area of Mixed Coastal Woodland in the south.

Temperate Tree Savannah is mainly ecotonal between grassland and woodland forms. Low Shrub Woodland occurs between the more extensive areas of Temperate Woodland and Shrub Steppe, and is characterised by the open to sparse nature of the low tree stratum and the presence of a discontinuous stratum of xeromorphic shrubs.

Temperate Woodland, the major type in the map area, includes communities dominated by evergreen sclerophyll trees, mainly Eucalyptus and Acacia or evergreen needle-leaved

Callitris spp. The trees have crowns which form an open to almost continuous canopy; the length of boles is not usually greater than the depth of the crown. The understorey is mainly herbaceous. Typically it occurs in areas of moderate (50-75 cm) rainfall on soils of moderate texture. A good deal of this vegetation type has been cleared for grazing and cereal agriculture.

iv) Forest

In the map area this comprises sclerophyll forest, generally divided by Australian authors into Wet Sclerophyll and Dry Sclerophyll Forest, and small areas of Temperate Rainforest.

The last-named type is confined to high-rainfall coastal areas (>130 cm rainfall). The canopy is dense and closed, and the understorey is usually limited to a sparse fern cover. Characteristic genera are Ceratopetalum and Atherospermum, while Nothofagus occurs south of 37°S latitude.

Wet Sclerophyll Forest is a closed community dominated by Eucalyptus spp. with interlacing flat crowns, below which a discontinuous stratum of small shade-tolerant trees may sometimes develop, typically species of Acacia, Pomaderris, Olearia and Bedfordia. There is usually a well-developed stratum of mesomorphic shrubs and a dense or sparse herbaceous stratum. This type occurs on the coast and in the higher rainfall parts of the Great Dividing Range (rainfall >90 cm), on moderately heavy textured podsols or loams with a high moisture holding capacity and moderate drainage. European influence on this vegetation type has been mainly confined to timber-getting, although extensive areas have been cleared for exotic Pinus plantations, and minor areas for agriculture and dairying.

Dry Sclerophyll Forest is separated from the previous community by the nature of the understorey, which consists of xeromorphic shrubs and a discontinuous herbaceous stratum. The eucalypt species also differ from the preceding type. This vegetation type occupies extensive areas, particularly on the Western Slopes, and in the rainshadow areas to the west of the mountains. Rainfall is generally greater than 60 cm, but edaphic factors are important in determining local distribution;

typically soils are of low moisture-holding capacity deficient in major or minor elements.

v) Alpine Complex

This is confined to the areas of the Great Dividing Range above 1700 m, and includes Subalpine Woodland, Sod Tussock Grassland, Bog, Herbfield, Feldmark and Heath communities. Its character is described in greater detail in the next section.

THE STUDY AREA

Topography, vegetation and siting of pollen traps in the region surrounding the Blue Lake study area are shown in Figure 1.4.

Topography

This is illustrated in plates 1.1.1 and 1.3. The Kosciusko Plateau occupies the western part of the map area. In character it is a rolling upland with broad valleys, sloping gently northwestwards from its highest point at Mt. Kosciusko (2228 m). The ridge of highest summits, including Mts. Kosciusko, Carruthers, Twynam and Tate is known as The Snowy Mountains, although this term is sometimes taken to mean the whole of the region, and colloquially as the "Main Range". To the east the plateau is deeply dissected by the valleys of the Crackenback (Thredbo) and Snowy Rivers. To the west the country falls steeply from the Plateau level of about 2000 m to the floor of the Geehi Valley at 400 m. The major streams draining this valley are the Geehi and the Swampy Plains Rivers, the latter tributary to the upper Murray or Indi River approximately 16 km to the northwest of the map area. The steep ranges of the Geehi Walls, culminating at Mt. Youngal, and the Grey Mares Range tend to enclose this valley. Slopes are moderate to steep except at lower elevations along Bridge Creek, and the alluvial Geehi Flats.

Vegetation

The vegetation of the alpine area has been described in most detail by Costin (1954) and McVean (1969); that of the Geehi Valley and the contiguous area of the upper Murray

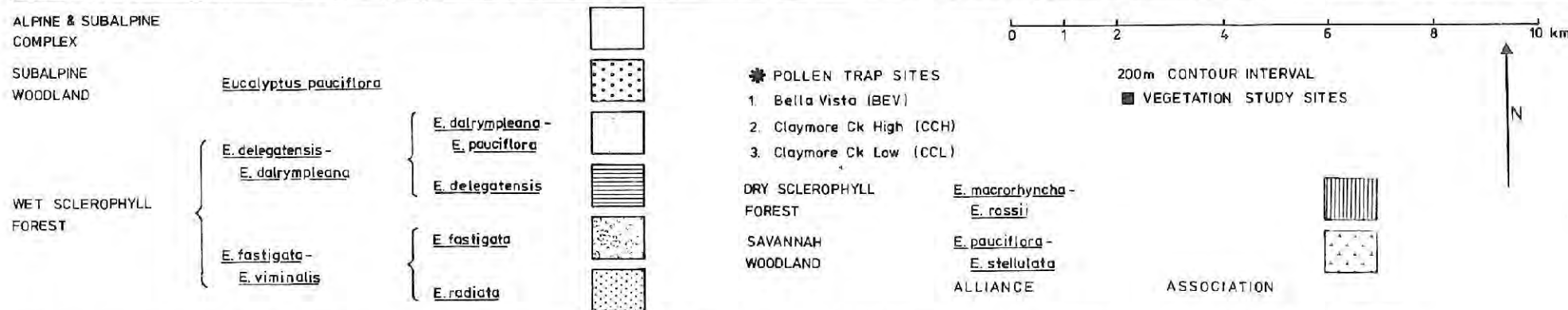
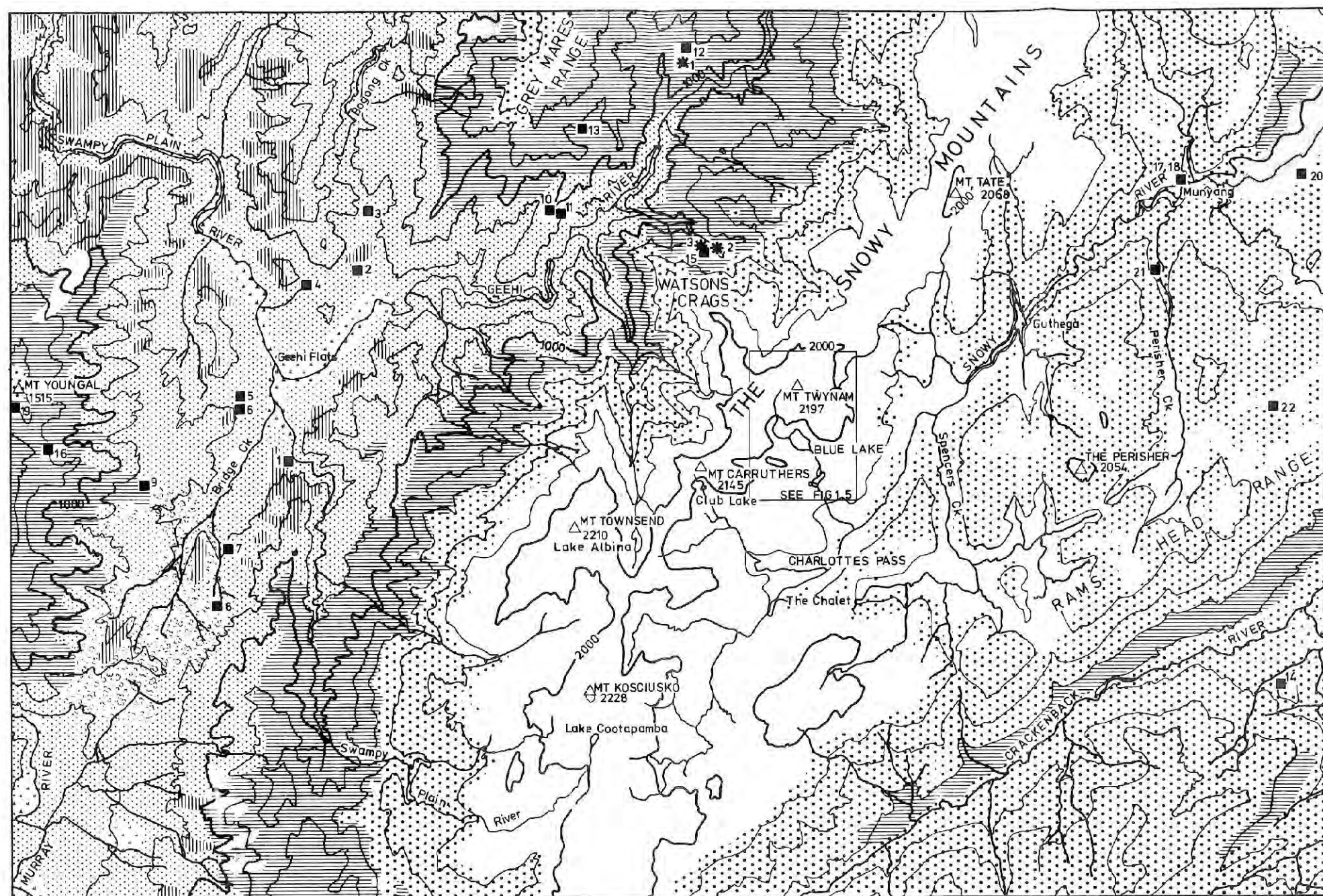


FIG. 1.4 VEGETATION OF THE SNOWY MOUNTAINS - GEEHI AREA. Mainly after Morland (1959), Costin et al. (1961) and Wimbush & Costin (1972)

River catchment has been described by Morland (1958, 1959). Vegetation maps of parts of the area shown in Figure 1.4 were presented by Costin (1954), Morland (1959), Costin et al. (1961) and Wimbush and Costin (1973). To supplement this work the author carried out a brief study of the forest vegetation by means of subjectively located 30 m quadrats, in which tree and understorey plant species were listed and rough estimates of relative foliage cover made. The results of this study are listed in Appendix C. Plant communities are described hereunder according to the formations recognized by Costin and Morland. These are basically physiognomic units of classification; the associations and alliances of these authors are based on the common structurally dominant species. Similar forests in the Australian Capital Territory have been described by Lang (1970).

i) Savannah Woodland

In the map area this is represented by a² small area of Eucalyptus camphora growing on the Geehi Flats on poorly drained prairie soils and red-brown earths. The originally parklike woodland was extensively cleared for grazing, but is now abandoned and largely overrun by blackberry (Rubus fruticosus). A large number of other alien species also reflect this disturbance; probably the original understorey was herbaceous and dominated by Stipa spp. (Poaceae).

ii) Dry Sclerophyll Forest (see vegetation study site numbers 6, 10, 11, Appendix C).

In the map area this is represented by small areas of forest dominated by E. dives. Co-dominant species include E. dalrympleana, E. radiata and E. bicostata. Usually the canopy is rather open, and there is a discontinuous layer of low sclerophyllous shrubs, typically Daviesia ulicifolia and Platylobium formosum (Papilionaceae). This formation is confined to shallow soils on ridge-tops, usually with northerly aspect, and to the drier area at the north-west corner of the map. See Plate 1.1.2.

iii) Wet Sclerophyll Forest (see vegetation study site numbers 1-5, 7-9, 13-16, 19-20).

Below approximately 1000 m this is represented by forest mainly dominated by E. radiata, although a small area of

E. fastigata occurs on deeper soils in the headwaters of Bridge Creek. Other small areas, typically on wetter slopes, are dominated by E. viminalis. E. bicostata occurs on some low-altitude sites. This is the most structurally complex and floristically rich of the forests of the area. Commonly several discontinuous shrub layers occur, usually with an herbaceous ground layer. On shaded slopes and in gullies, tree ferns (Dicksonia antarctica) and terrestrial ferns may form an understory to an almost closed sub-canopy of small trees of Pomaderris aspera, Bedfordia salicina, Olearia argophylla and Acacia spp. (Plate 1.2.1). At intermediate altitudes small pockets of rain-forest with Atherosperma moschatum as the only dominant occur in similar situations. These may pass up into the lower levels of wet sclerophyll forest dominated by E. delegatensis.

E. delegatensis forms almost pure stands extending from the upper limit of E. radiata forest to E. pauciflora subalpine woodland. Co-dominants include E. dalrympleana. Floristic diversity appears to decrease with increasing altitude but it does not seem likely that there is a distinct discontinuity in the understory flora corresponding to the transition from E. radiata to E. delegatensis dominated stands. There does, however, appear to be such a break at about the upper limit of the formation, probably corresponding to the greatly increased incidence of winter snow cover. Typical understory shrubs include Tieghemopanax sambucifolius, Correa lawrenciana, Coprosma hirtella, Lomatia myricoides and Prostanthera lasianthos. On drier aspects, the higher altitude wet sclerophyll forest may have as dominant species E. dalrympleana and E. pauciflora. Stands of this community are lower and have a more open canopy than the E. delegatensis forests, and there is a greater development of herbaceous understory. These forests appear transitional in structure and floristics to subalpine woodland.

iv) Subalpine woodland (vegetation study sites 17, 18, 21, 22)

This is dominated by E. pauciflora, with occasional trees of E. perriniana and E. dalrympleana at lower elevations. On steep slopes, at lower levels, and where coppiced by fire damage, this species forms a forest with closed canopy, but at higher elevations is typically open and park-like. The understorey consists of shrubs on the wetter, more shaded, and poorer sites, and is grassy in sunnier, drier, aspects.

On the north-western slopes of the Kosciusko Plateau, the tree-line is simple and maintains a general level of about 1750 m, rising to higher altitudes on northerly-facing slopes than on southerly slopes, possibly because of higher insolation and lesser snow accumulation. The tree-line appears to correspond in mean altitude to a mean temperature for the warmest month of about 10°C, as in other parts of the world (Wimbush & Costin, 1973).

On the Plateau itself, the distribution of woodland is complicated by the occurrence of areas of snow accumulation, high ground-water levels, and cold-air drainage. These latter two factors produce an inverted tree-line (Plate 1.2.2.) in subalpine valleys.

v) Alpine Complex

This is shown as a single unit in Figure 1.4., but is composed of several distinct plant communities. Characteristic distribution of these communities with respect to aspect and topography is shown in the vegetation map of the Blue Lake area, Figure 1.5. These mapping units, with the exception of Chionochloa Tall Alpine Herbfield and Short Heath, represent alliances or alliance complexes of Costin's (1954) classification. Correspondence of this classification with that of McVean (1969) is given by Wimbush & Costin (1973).

Windswept Feldmark is confined to the most windswept saddles and ridges. Plants of the main dominant species Epacris microphylla and in a few locations Epacris petrophila are distributed sparsely but fairly regularly in a stony pavement. Cyclical development in this community has been

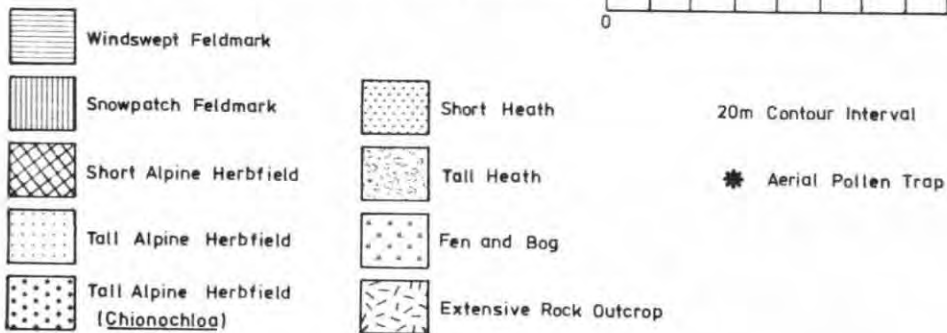
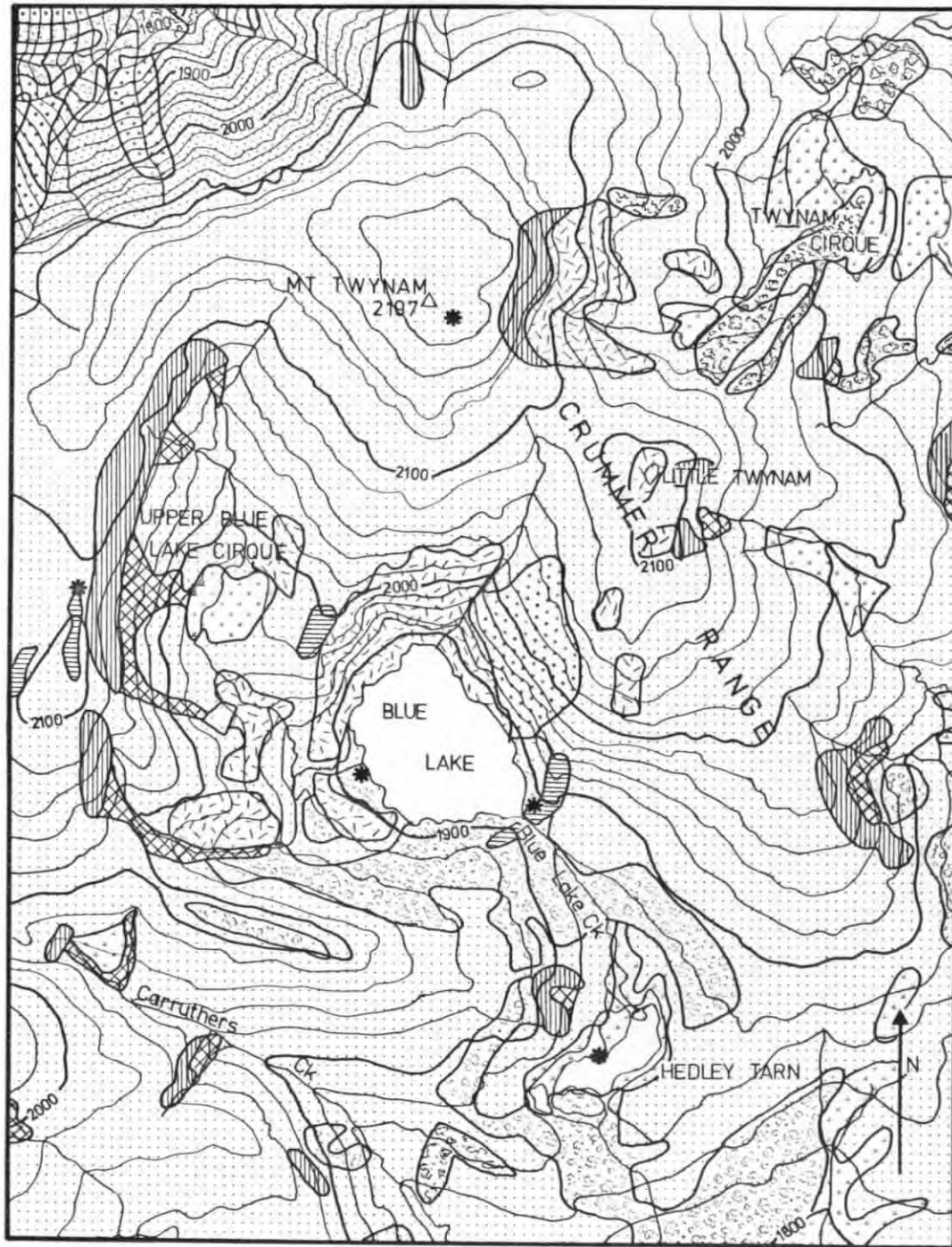


FIG. 1.5 VEGETATION OF THE BLUE LAKE AREA
(modified from Wimbusch & Costin, 1973)

described by Barrow, Costin & Lake (1968), while Costin, Thom, Wimbush & Stuver (1967) indicate the past extension of the area of the community.

Snowpatch Feldmark, dominated by cushion plants of Colobanthus spp. is confined to freely drained, rocky, upper snow-patch situations where snow lasts for most of the year. Mapped areas include some completely bare snowpatch sites.

Short Alpine Herbfield is confined largely to small patches immediately downslope from the snow-patch areas, receiving considerable runoff from late-lying snow. Typical dominants are low-growing Neopaxia australasica, Plantago spp., Caltha introloba, Ranunculus spp., Dichosciadium ranunculaceum and Oreobolus spp., among a complex of gravelly melt-water stream beds. Other important occurrences of this vegetation type are among moist rocks of the cliffs and outcrops around the head of Blue Lake, and in Twynam Cirque.

Tall Alpine Herbfield is the most extensive plant community in the alpine area. The main dominants are the snow daisy Celmisia longifolia and snow grass Poa spp. Other important herbs are other Asteraceae, Euphrasia spp., and Apiaceae. Scattered shrubs of Phebalium ovatifolium, Prostanthera cuneata and other shrubs commonly occur, indicating transition to the Tall Heath of more insolated sites.

Chionochloa Tall Alpine Herbfield is a distinctive tussock grass community included by Costin (1954) in his Celmisia longifolia - Poa caespitosa alliance. A common but not exclusive associate is Aciphylla glacialis (Apiaceae). Typical habitats of this community are the steep western slopes of The Snowy Mountains. An extensive area also occurs on the northern side of Blue Lake.

Short Heath is characterized by a dense canopy of low-growing shrubs of Kunzea muelleri and Epacris microphylla, generally less than 25 cm high. Typically it occurs in exposed situations on westerly-facing slopes. It grades into Windswept Feldmark in more exposed situations and into Tall Heath under less exposed conditions.

Tall Heath varies in height from 30 to 90 cm, and is second in extent to the Tall Alpine Herbfield. It forms the understorey of subalpine woodland where this is shrubby. A variety of shrubs may be dominant, including Prostanthera cuneata, Grevillea spp., Phebalium spp., Orites lancifolia, Drimys xerophila, Oxylobium spp., Olearia spp., Pimelea spp. and Podocarpus lawrencei, the last typically in rocky exposed situations.

Bogs are shrubby, with dominant Epacris spp. and Richea continentis growing through a sublayer of Sphagnum and Astelia spp. They occur mainly in seepage areas, and many occurrences have probably been included in the area of Tall Heath.

Fens are dominated by Carex and Scirpus spp., and occur mainly along drainage lines with greater sediment supply than sites occupied by bog communities (see Plate 1.4.2).

Disturbance of the vegetation by man

Although it is generally agreed among Australian ecologists that at least the drier types of Eucalyptus forests are adapted to regeneration after fire, the pre-European frequency of fires is only guessed at, although current dendrochronological studies may throw some light upon the problem.

Hancock (1972) has reviewed early accounts of Australian aboriginal practices in the Monaro region, and indicates that fires were deliberately set by the aborigines, but whether for pleasure or profit is not known. The aboriginal population, always apparently small, was soon completely displaced by European settlers after their arrival in the region in the 1830's. Early graziers followed the practice of burning the woodland and grassland country to increase the availability of grasses palatable to stock. The long term effects of this practice are not fully known, but it is suspected that permanent change to shrub-dominated communities occurred in some areas.

Grazing in the alpine areas during drought years in the early part of the present century caused severe erosion along the crest of The Snowy Mountains and, together with burning, reduced the extent of bog communities and the relative abundance

of forbs in the herbfield communities (Costin, 1959). Grazing after severe fires also prevented coppice and seedling regeneration of Eucalyptus pauciflora subalpine woodland and increased the open nature of this community.

The reservation, in 1944, of most of the alpine and subalpine area as the Kosciusko National Park reduced the extent of grazing at higher levels, although this was not finally eliminated until the 1960's. Considerable regeneration of many communities has been noted since this time.

Further disturbance, in localised areas only, but there severe, was caused by construction of the Snowy Mountains Hydro-Electric Scheme, beginning in 1949, and now essentially completed. Most disturbed areas were revegetated with exotic species, but these do not appear to have spread into the native vegetation.

To sum up, there was little effect by European man on the wet sclerophyll forest areas, although the effect of his advent on the frequency of fires, a factor possibly important in the natural ecosystem, is not at present known. Clearance of the small area of savannah woodland, and probable thinning of subalpine woodland in the area to the east of The Snowy Mountains were the most important effect of European grazing activities in the area indicated in Figure 1.4. Reduction of the extent of bog communities and the forb content (as opposed to the unpalatable Poa tussocks) of the alpine herbfield also occurred, although these communities have recovered to some extent since protection.

Geomorphology and Geology

Granite rocks form most of the area of Figure 1.3, but metasediments (slate, phyllite, schists, quartzite) occur in northeasterly-trending belts along the crest of The Snowy Mountains, along the floor of the Geehi Valley, and on the eastern slopes of Mt. Youngal.

Evidence for Pleistocene glaciation was first discussed by W.B. Clarke about the middle of the last century (see Galloway, 1963). Later workers (e.g. Browne & Vallance, 1970) postulated that there were three successive glaciations consisting of an ice-cap stage covering about 1000 km², a stage of valley glaciers and a final cirque glacier stage. Galloway,

on the other hand, has argued convincingly that there is satisfactory evidence for only a limited cirque and valley-head glaciation of at most 50 km² in extent, although he indicated that the so-called David Moraine was a possible remnant of an earlier extensive glaciation. This and other glacial features mapped by Galloway (1963) are indicated in Figure 1.6. Galloway concluded that the period of maximum glaciation was of middle Würm age, from the relatively unweathered state of the moraines.

Periglacial, and sedimentary deposits have provided a more definite chronological framework of late Quaternary climatic events. Costin (1972) has provided a recent summary of the available information.

The oldest dated deposits (Costin & Polach, 1971) are widespread solifluction deposits several metres thick which coat most slopes and are particularly well developed between 1200 and 1500 m. The lower limit is indefinite, but is probably lower than 1000 m. These deposits are dated at 31000-34000 years B.P. by radiocarbon assay. Blockstreams also of periglacial origin have been dated by Jennings & Caine (1968) from the Toolong Range, to the northwest of the study area, at 35000 years B.P., a date obtained from a Nothofagus stump buried beneath the rubble. This and organic soils at the base of the solifluction deposits are indicative of milder conditions immediately prior to the cold period, possibly the same period as that of maximum extent of the cirque glaciers.

Laminated deposits within an outer moraine in Twynam Cirque have been dated at c.20000 years B.P. to 8600 years B.P. Costin interprets these deposits as forming after the main period of glaciation, but while a small glacier or semi-permanent snow-patch continued to exist in the upper part of the cirque. Further details are given in Chapter 3.

Basal fen peats, in the upper Snowy River valley and above Carruthers Creek have been dated at 15000 and 14400 years B.P. respectively, indicating that deglaciation of at least some alpine sites had occurred by 15000 years ago.

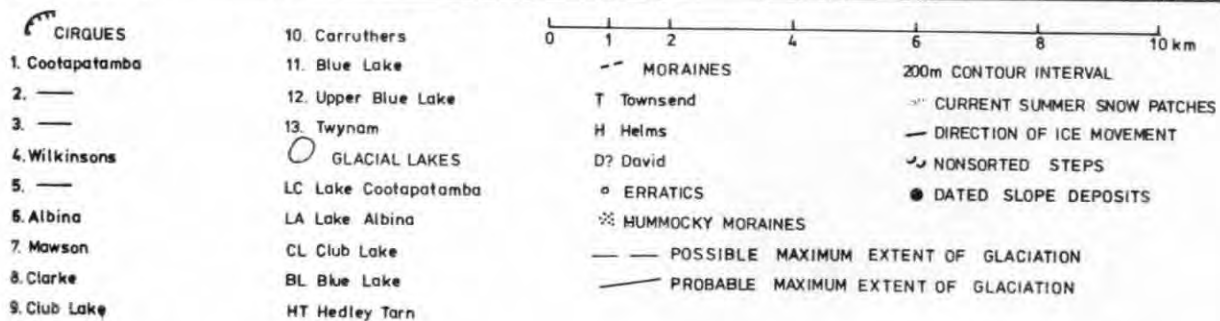
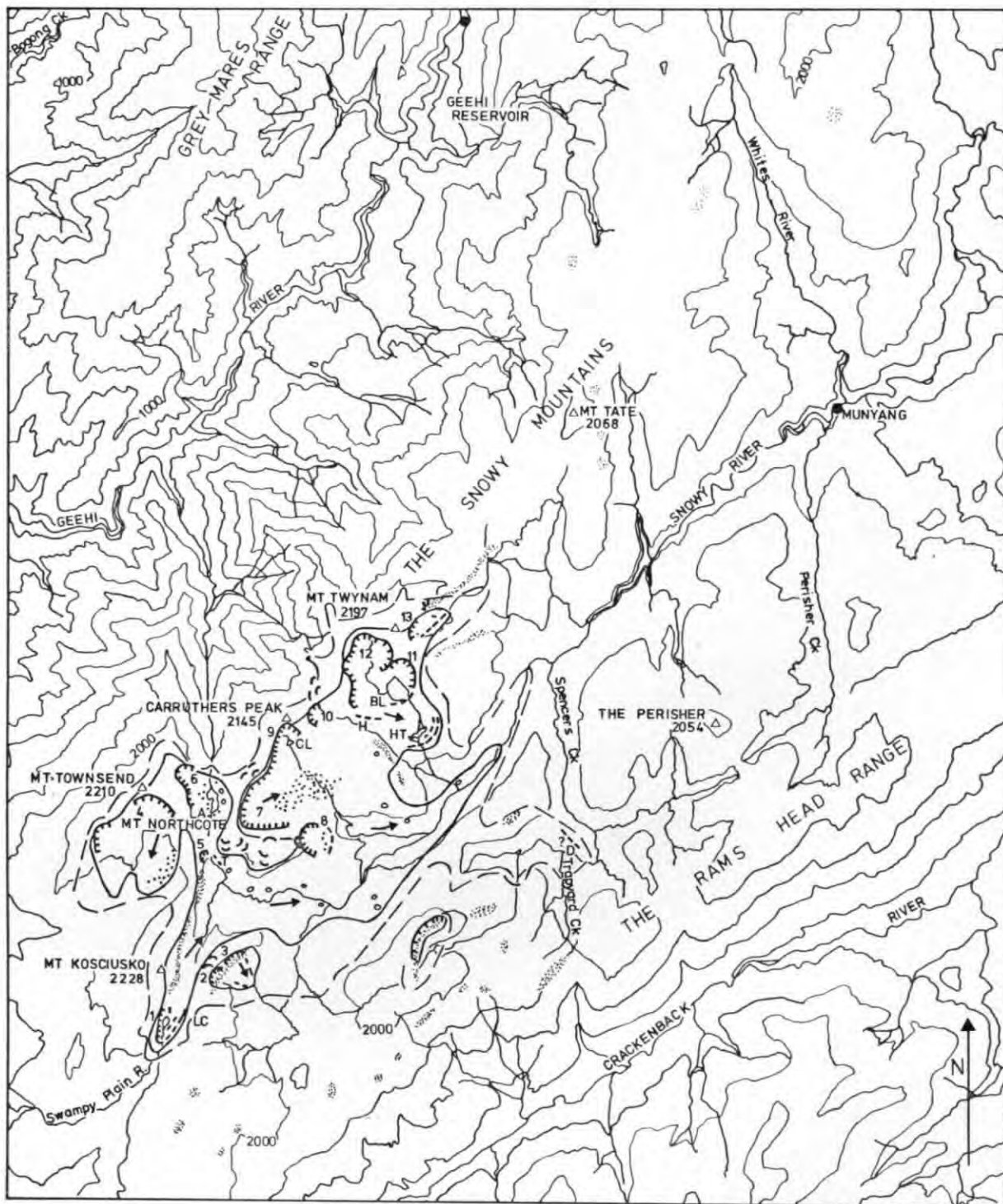


FIG. 1.6 GLACIAL AND PERIGLACIAL FEATURES IN THE SNOWY MOUNTAINS.
Mainly after Galloway (1963) and Costin et al. (1967).

Peats in valley - floor situations near Perisher Creek, and in Twynam Cirque and Upper Blue Lake Cirque have yielded basal dates of between 8000 and 9000 years B.P. Costin attributes these later dates to the persistence of small glaciers and névés in these sites until above 9000 years ago.

Nonsorted steps, a periglacial feature consisting of lobe-like bodies of poorly sorted silt and stones, occur on exposed sites on metasediments along the crest of The Snowy Mountains (see Figure 1.6) (Costin et al., 1964). Radiocarbon dates on buried fieldmark plants indicate that solifluction was active 2000-3000 years ago and again as recently as 300 years ago. These features suggest a mean annual temperature of at least 3°C less than present, without significantly greater snow cover (Costin, 1972). Similar ages for certain alpine and subalpine basal peats suggest that previously existing peats may have been stripped by periglacial action under colder conditions.



Plate 1.1.1 Winter view of the western slopes of The Snowy Mountains from Mt. Youngal. Treeline is at about 1750 m.



Plate 1.1.2 Dry Sclerophyll forest of the Eucalyptus macrorhyncha - E. rossii association in the Geehi Valley.



Plate 1.2.1 Wet sclerophyll forest of the Eucalyptus radiata - association in the Geehi Valley. There is a dense understorey of tall shrubs, mainly Bedfordia salicina (Asteraceae) and Pomaderris aspera (Rhamnaceae).



Plate 1.2.2 Subalpine woodland of the Eucalyptus pauciflora association in the headwaters of the Geehi River. Treeless valley floors, due to cold air pondage, are typical of the lower part of the Kosciusko plateau.



Plate 1.3 Blue Lake and the alpine area to the east of the divide, looking southeast. Darker vegetation is heath, lighter herbfield. Chionochloa tall herbfield above lake left. Subalpine woodland can be seen around Charlotte Pass.



Plate 1.4.1 Blue Lake frozen in early winter, looking west towards the Upper Blue Lake Cirque and the main divide on the skyline. Efflux aerial pollen traps in foreground.



Plate 1.4.2 Upper Blue Lake Cirque in early summer. Herbfield in foreground is dominated by *Euphrasia* spp. Fen on lower ground, with eroded herbfield below snowdrift. Darker communities below drift are short herbfield.

CHAPTER 2

POLLEN SAMPLE COLLECTION AND PREPARATION
TECHNIQUESFIELD COLLECTION OF PALAEOPALYNOLOGY SAMPLESBlue Lake Sediment Cores

Eight cores were taken from five sites in Blue Lake with a Mackereth corer (Mackereth, 1958) operated from a pair of small boats. At the central lake site (1) an attempt was made to increase the depth of coring by extending the basic 442cm long core barrel and fixed piston of the ANU corer. This was done by attaching successive 154cm lengths of core barrel and fixed piston tube with dummy fixed piston at the end, as described by Smith (1959). The extension was forced into the mud by the weight of the device and by the anchoring procedure prior to the coring stroke.

Extensions of 154cm (giving core from 164-596cm depth) and 2 x 154 cm (giving core from 318-750cm depth) were successful, but in an attempt with a third extension the corer did not anchor properly and a shallow core resulted. Theoretical coring depths for the basic corer and corer plus extensions, based on corer dimensions, were:

	Depth of uppermost Sample (cm)	Depth of lowermost sample (cm)
basic corer	10*	442
Corer + 1 extension	164	596
Corer + 2 extensions	318	750

* The corer does not sample the topmost few cm of the deposit.
Diameter of the core was approximately 41 mm.

Recovered cores were extruded on the lake beach into plastic troughs, measured, wrapped and thoroughly sealed in plastic film and split PVC plastic tube, and returned to the laboratory for sampling and further description.

Sections of core reveal very little distortion of sedimentary lamination, where this is present, only the outermost 2 mm being smeared along the core. Laminations in some cores show up to 7° dip to the horizontal (i.e. perpendicular to the lengthwise direction of core). It is not clear whether

this is due to drag during recovery of core from the core barrel, to slant of the corer during the coring stroke, or to original sedimentary dip, but in any case, the observed dips are not sufficient for correction of depths to be necessary.

Core recovery was close to 100% except in the mis-run with three extensions and at the thin-sediment site 5. With three cores the measured length slightly exceeded the core barrel length, this being due to slight breaks in the core during extrusion, or to slight expansion of the core due to leakage of gas past the fixed piston into the core. In some cases there was a slight loss of core at the open end of the corer due to extrusion under hydrostatic pressure when the corer sank before recovery.

Sample depths were corrected, where necessary, for expansion of the core. An arbitrary depth of 10 cm was assumed for the depths of core tops. Correlation of cores taken with extension tubes at the central lake site was checked by comparison of sediment stratigraphy and by comparison of pollen diagrams from the upper and lower cores, using the computer program CORRIE written for the purpose (see Appendix B). Radio-carbon age determinations and absolute pollen counts provided a further check. Details of core stratigraphy are presented in Chapter 3.

Twynam Cirque Section

Samples were collected from this site by inserting plastic vials into selected strata exposed in a stream bank section which had been cleaned-down with a shovel. These vials were then capped, labelled, and returned to Canberra for processing. Details of the site are presented in Chapter 3.

SELECTION, CALIBRATION AND SAMPLING OF POLLEN TRAPS

Selection

A primary aim of the study was to measure the rate of pollen input into the lake from the atmosphere. For this natural pollen traps, such as moss polsters, for which neither the period of pollen accumulation nor the extent of preservation of accumulated pollen would be known, could not be used.

Artificial devices which sample airborne pollen may be classified into three groups on the basis of the quantities they sample.

The first group consists of devices which, with varying degrees of accuracy, sample the concentration of pollen in the air. The Rotorod sampler (Perkins, 1957) and membrane filter samplers (e.g. Harrington *et al.*, 1959, but there are many commercially available types) are examples of this group.

The second group consists of devices which sample the horizontal drift of pollen, such as cylinder samplers (Raynor *et al.*, 1961). These require a record of wind speed or run if it is desired to convert pollen flux into concentration estimates, but may directly estimate pollen impaction onto vegetation.

The third group of devices, to a greater or lesser degree, simulate the collection of pollen by a bog or lake surface, and thus sample the vertical drift of pollen, or pollen deposition.

Selection of a device of the first or second groups for this study, apart from practical difficulties, would have involved estimation of pollen deposition rates from atmospheric concentration or horizontal pollen drift or flux. This would entail estimation or measurement of atmospheric turbulence, wind speed, etc., as well as pollen physical parameters, since studies on deposition of particles have shown these factors to be important (Gregory, 1945; Chamberlain, 1961; Hage, 1961; Melpar, 1969; Edmonds, 1971).

While studies of this kind are of great importance, they were beyond the resources and scope of the present work. Thus attention was turned towards the third group of samplers. Among the criteria which a prospective sampler had to satisfy were the following:

- i) Collection of a sample which could be related qualitatively and quantitatively to collection by a natural surface such as a lake.
- ii) Operation for periods of at least a month, preferably longer, without serious loss of trapping efficiency.
- iii) Reliability and continued effectiveness under extreme weather conditions (high wind, rain, snow, icing).

- iv) Operation unattended and without major power supply.
- v) Cost, seeing that several samplers would be required.

Criteria ii) to iv) ruled out samplers such as sticky slides or films. A sampler of the raingauge type was indicated. The trap described by Tauber (1967), subsequently referred to as the Tauber trap, appeared to have advantages over the common raingauge in that its smoothly curved upper surface, based on a design for an improved sticky slide holder by Ogden and Raynor (1960), suggested that turbulence effects at the orifice of the sampler might be minimised. As discussed in the Introduction, the trunk-space component of the pollen flux is not likely to be important in the case of a lake such as Blue Lake, where the vegetation may be regarded as a source of zero elevation. Thus elevation of pollen traps above the vegetation canopy was necessary. Because wind speed and turbulence increase with height above the canopy (Geiger, 1965), the Tauber trap was the logical choice, whereas for below-canopy studies the difference between simple raingauge-type traps and Tauber traps might not be important.

It was necessary, however, to investigate the behaviour of the Tauber trap as a quantitative collection device. Wind-tunnel studies were therefore carried out. After the completion of these the author received a pre-print of a paper by Tauber on the same subject (Tauber, 1974). The results of these two studies are compared in the next section.

Calibration

i) Description of the Tauber trap

Traps used in the field in this study consisted of a PVC plastic cylinder 30 cm high and 10 cm in internal diameter, closed at the base by a PVC plastic plate, and at the top by a machined perspex lid, 15 cm in diameter, with a central circular orifice 5.11 ± 0.02 cm in diameter (area of orifice 20.54 ± 0.14 sq. cm). The lid was tapered in thickness towards the circumference, and the outer edge and inside edge of the central orifice were rounded (see fig. 2.1). Countersunk brass screws secured the lid to the body of the trap. All dimensions were similar to those of the original, save the cylinder length, which was increased from 10 cm to allow a greater accumulation of rainfall. It is not expected that this difference would significantly affect collection efficiency.

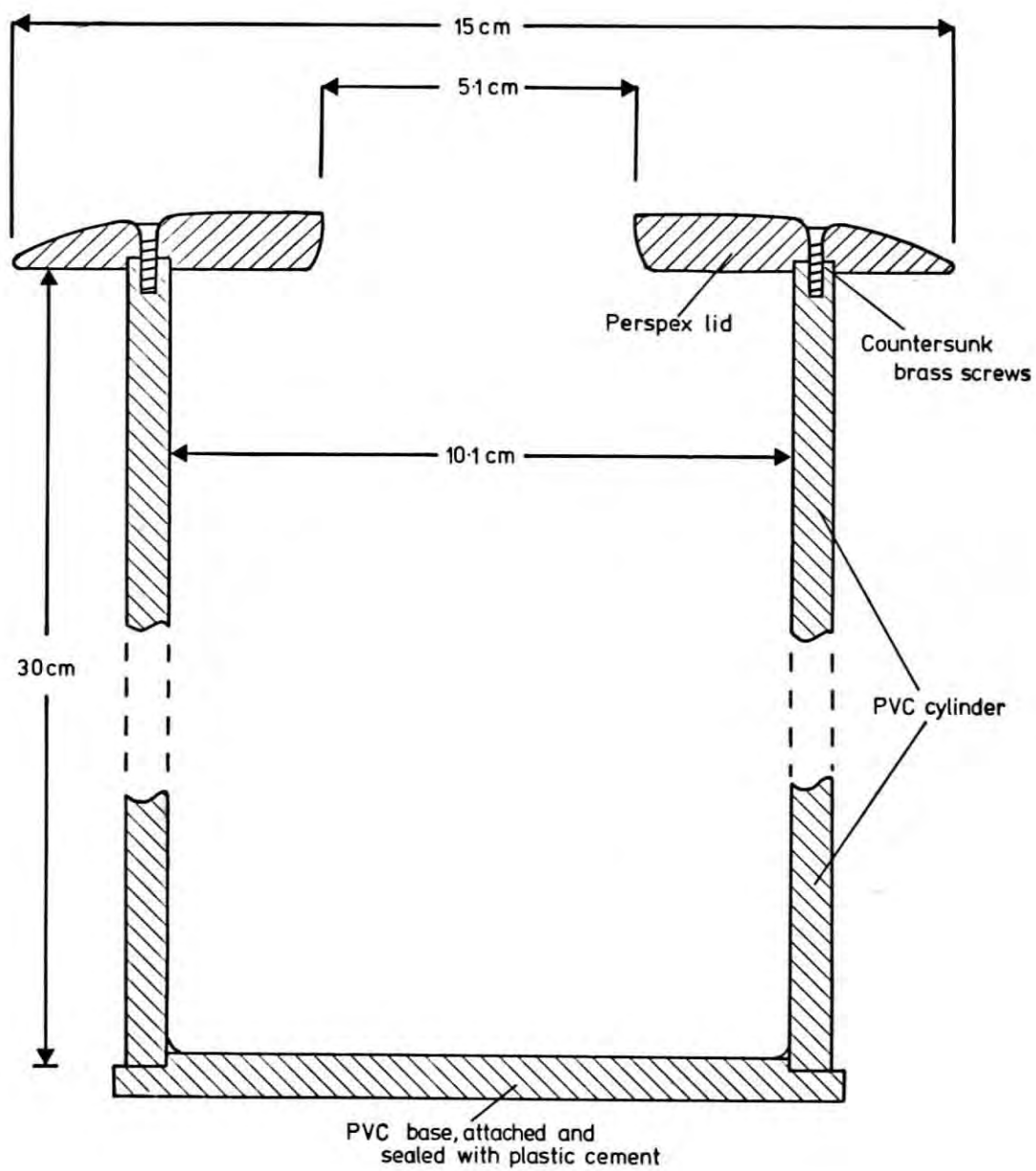


FIG. 2.1 VERTICAL CROSS-SECTION OF A TAUBER TRAP

In the field 250 cc of a 20% aqueous solution of glycerol was added to each trap at the initiation of a trapping period, to ensure a permanently wet collection surface at the base of the trap. This solution also contained 1% mercuric chloride as a preservative.

ii) Air flow over the trap

While air flow over a surface of similar shape to that of the trap lid was described by Ogden and Raynor (1960), it was decided to check the behaviour of the locally-made traps.

The wind-tunnel used in this and the subsequent series of experiments was a non-recirculatory type. Laboratory air was sucked through a honeycomb straightener (Plate 2.1, 5) and passed through a tapering section before entering the 1 m long working section, which had a height of 35 cm and width 30 cm. The roof and door of this section were of perspex to allow observation and photography. Air left the working section through shutters which allowed variation of the wind speed. The fan was situated at the end of a dilating section; two fan speeds allowed coarse adjustment of wind speed.

Turbulence was not measured, but was estimated by the designer of the tunnel to be of the order of 1% (Dr. F. Bradley, pers. comm.) in the empty tunnel.

Because of the small cross-sectional area of the tunnel, a trap of 10 cm cylinder height was used: this corresponds to the size of trap used by Tauber (1974).

Titanium tetrachloride smoke was dispersed from wires held in front of the tunnel entrance. Smooth flow of air, as expected, was demonstrated at wind speeds up to 16 m/sec (see Plate 2.1, 3).

iii) Collection efficiency at various wind speeds

Before traps were placed in the tunnel, the effectiveness of the particle dispenser was tested. This makeshift device (see Plate 2.1, 5) consisted of a small vacuum cleaner used as a blower, together with a metal funnel with a reservoir for particles fitted with a tap. Upon opening the tap, particles were sucked into the air stream in the neck of the funnel, then encountered baffles in the broader part of the funnel, these being intended to introduce turbulence and so disperse the particle cloud. At this time the author was not aware of the compressed-air operated device described by Gregory (1951) and used by Tauber.

In order to determine evenness of distribution of the particle cloud over the cross-section of the tunnel, five vertical 1 mm diameter wires were fixed in place in the working section of the tunnel, on the same perpendicular cross-section and equidistantly spaced from each other and the tunnel walls. These were coated with a solution of Canada balsam in xylene immediately prior to the experimental run. Upon evaporation of the xylene a sticky film of balsam of even thickness remained. The same solution was used to coat Rotorod samplers in later experiments, as the more commonly used rubber cement was not available. (As noted by Tauber, it is difficult to secure an even coating with silicone grease).

Homogeneity of wind speed over the sampler cross-section of the tunnel was investigated with a pitot tube and inclined manometer. Variation from the tunnel axial speed did not exceed 1% except within 1 cm of the tunnel wall.

Commercial Lycopodium spores, of Lycopodium clavatum type, were dispersed at a wind speed of 2 m/sec, as determined by pitot tube. The mean size of these spores, determined by calibrated microscope ocular measurement of maximum diameter of 10 grains in silicone oil suspension, together with mean sizes of pollen types used in later experiments, are listed below.

<u>Lycopodium</u> (D.H.A.)	31.3 ± 1.9 μ
<u>Tsuga canadensis</u> (Greer laboratories)	63.0 ± 3.1 μ
<u>Pinus radiata</u> (F.R.I.)	51.9 ± 3.1 μ
<u>Ambrosia trifida</u> (Greer laboratories)	19.9 ± 0.7 μ

After exposure, the wires were removed from sources of contamination and later chopped into 5 cm lengths for counting of grains under a binocular microscope. Analysis of variance of counts for these wire sections failed to demonstrate significant variation of spore concentration over the cross-section of the tunnel. After completion of the experiments, it was evident from the density of spore deposit on the honeycomb straightener that spore concentration probably fell off near the walls of the tunnel, however since samplers were placed in the central part of the cross-section, it is concluded that variation in spore dosage between the samplers tested was not significant.

Examination of the wires also showed that spores impacted as single grains, not as aggregates of grains, so that the results presented below refer to the collection of single grains.

After removal of the wires, the 10 cm high Tauber trap was placed in the tunnel, together with a Rotorod sampler and a membrane filter sampler (see Plate 2.1, 4 and 6). The latter consisted of a sharpened metal tube fitted to a commercially available membrane filter holder. Suction was provided by an air pump with vacuum reservoir, and controlled by a needle valve and flow meter. Air flow through the device was regulated to a rate just below that required for isokinetic sampling. The tube was directed into the air stream. Under these conditions, the catch of spores on the filter should, when divided by the cross-sectional area of the orifice, provide an unbiased measure of the total number of spores passing through unit area at right angles to the wind stream. Spores were counted under a binocular microscope by mounting on slides and counting the number of spores encountered in regularly spaced traverses. The total number of spores caught on the filter was then calculated, assuming that spores were evenly distributed over the filter. This was substantiated by Chi-square tests on counts per traverse.

The Rotorod sampler (Perkins, 1957; Edmonds, 1972) is a rotating arm inertial impaction sampler. Arms used in the study were H-shaped chromel Rotorods supplied by the manufacturer. These have arms 12 cm apart with impaction surfaces 0.038 cm wide and 6 cm high. At the 2380 rpm rotation speed for the sampler used (certified by the maker), peripheral velocity was 15.0 m/sec. As the arms sweep the air at a constant rate, the device effectively functions as a sampler of mean particle concentration.

The ratio $\frac{\text{no. of particles caught}}{\text{no. of particles in swept volume}}$ is known

as the collection efficiency. This depends on the nature of the sticky surface used to retain particles, and on particle size and density. While there are theoretical treatments of collection efficiency in terms of fluid and particle parameters, the experimental data of Noll (1970), which were derived from studies with a sampler of similar type, are preferred (Edmonds, 1972).

Particle parameters are combined with fluid parameters to calculate the dimensionless parameter P:

$$P = \frac{V d^2 \sigma}{18n L S}$$

Where V = air speed perpendicular to Rotorod arm

d = diameter of sphere of equivalent volume to that of particle

σ = density of particle

n = viscosity of air

L = width of rectangular section collector

S = shape factor of particle (= 1 for spheres)

The highest wind tunnel speed used in the tests was 12 m/sec, so that the minimum differential air speed V encountered by a whirling Rotorod arm would be (15-12) m/sec, that is 3 m/sec. Using V = 300 cm/sec, d = 31 x 10⁻⁴ cm, σ = 1 gm/cc, n = 182.7 x 10⁻⁶ g/cm/sec (at 18°C), L = 0.038 cm, S = 1, P is equal to 23.1. Since for P greater than 10, the efficiency of collection (ignoring surface retention) is close to 100% (Edmonds, 1972), it is close to 100% for all air speeds used (P increases with increasing differential arm speed).

With regard to surface retention efficiency, the makers quote sampling rate figures which suggest that rubber cement has a 67% retention efficiency while silicone grease has 50% retention efficiency (Metronics, 1966). It is not stated how these figures were derived. Harrington et al. (1959) quotes a figure of 40% for adhesive efficiency of rubber cement used on a stationary cylinder-type sampler, from wind-tunnel experiments. In the present series of experiments comparison of rotorod and filter sampler results suggests a value of between 40 and 95% for the adhesive efficiency of the Canada balsam used. The spread of results prevented a closer estimate: the efficiency may in fact vary from one application to another (see figure 2.2). In view of this uncertainty dosage figures were not corrected for adhesive efficiency.

Rotorod collection surfaces were counted under a binocular microscope after mounting in a frame to fit the traversing stage used. The total number of grains along 1 cm of collection surface was determined by addition of six successive microscope fields of diameter 1/6 cm. Chi-square analysis of counts from individual fields in several cases

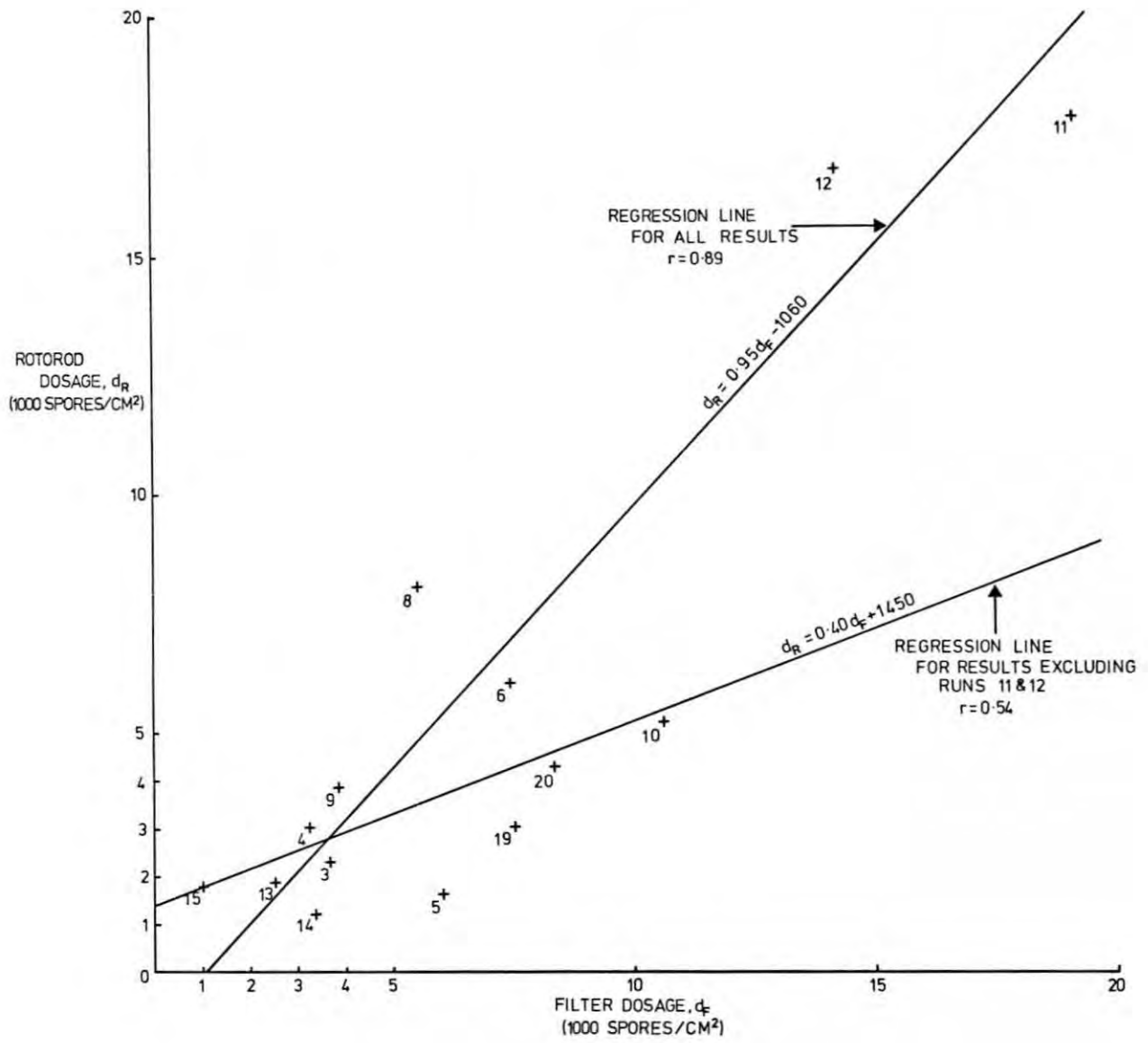


FIG. 2.2 COMPARISON OF ROTOROD AND FILTER SAMPLER RESULTS

showed significantly different counts between fields. In such cases counts were repeated for a different section of the Rotorod. This did not always result in acceptable figures. In some cases the distribution of spores on the Rotorod suggested contamination after the wind-tunnel run, but in other cases this seemed unlikely. This will be returned to later.

Rotorod counts were reduced to dosage figures by the

$$\text{formula dosage} = VN/2 \pi r a f$$

where V = ambient air flow (cm/sec)

N = spores/cm length of collector surface

r = radius of collector rotation = 6 cm

a = area of collector surface/cm length = 0.038 cm

f = rotation rate of collector = 2380 rpm

The Tauber trap contents were collected after each run by washing into a jar with copious quantities of wash water and alcohol. These samples were later filtered on membrane filters (as described subsequently under preparation techniques), and trap total spore catch determined by counting selected traverses of these filters under a binocular microscope, as described for filter trap membranes. Trap dose/sq. cm was calculated by dividing total spore catch by the orifice area of the sampler, 20.54 sq. cm.

Results of runs at various wind speeds between 1 m/sec and 12 m/sec, with the three devices in place, and with Lycopodium spores, are tabulated in Table 2.1. Wind speed was determined by a pitot tube placed between the traps prior to admission of spores. The collection efficiency of a horizontal trap surface is conventionally expressed as

$$E = \frac{\text{trap dose} \times 100\%}{\text{area dose}}$$

where trap dose is the number of particles caught per unit horizontal area and area dose is the number of particles passing through unit area at right angles to the air flow (Gregory, 1961). Values of E derived from both rotorod and filter trap results are tabulated, and plotted in figure 2.3.

While there are some deviant values, the general trend is that of an approximately inverse relationship of E with wind speed. The experimentally derived curve of Tauber

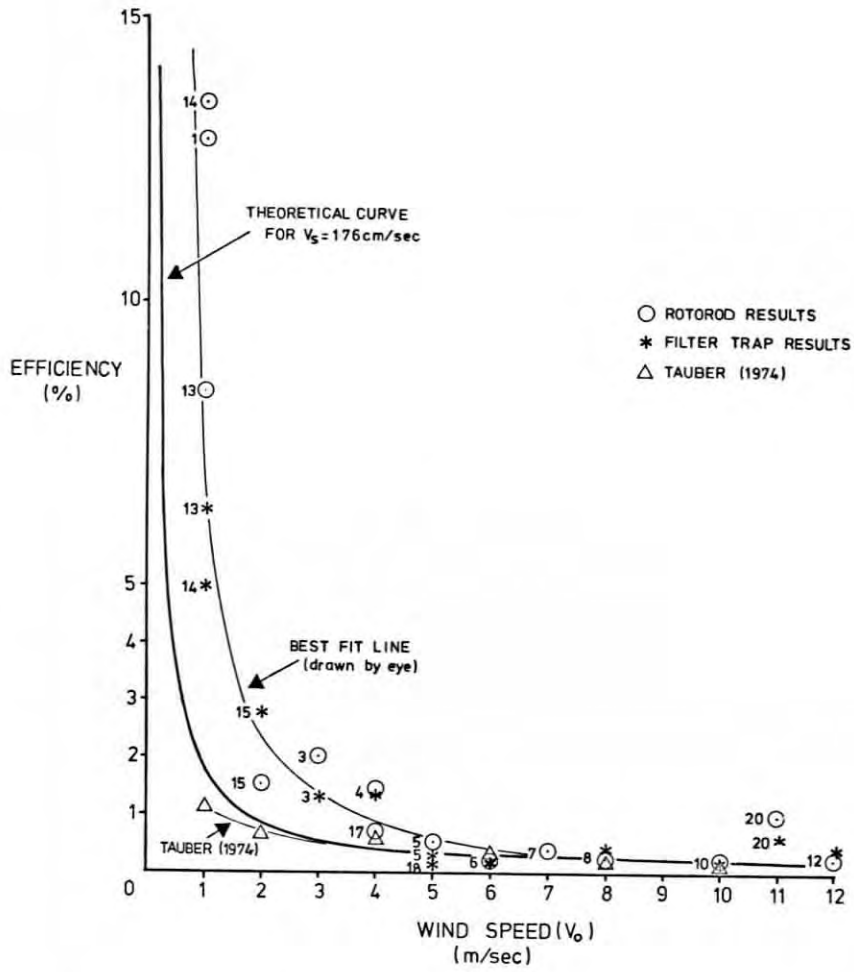


FIG. 2.3 EFFICIENCY OF TAUBER TRAP AS A FUNCTION OF WIND SPEED
(EXPERIMENTAL RESULTS)

for Lycopodium spores is also plotted, together with a theoretical curve drawn according to the law:

$$E = \frac{V_s}{V_o}$$

where V_s = settling velocity of particle in still air
 V_o = wind speed

This equation follows from the preceding definition of E when the following substitution is made:

$$\text{trap dose} = \frac{\text{area dose} \times \text{settling velocity}}{\text{wind speed}}$$

The theoretical curve is plotted for $V_s = 1.76$ cm/sec (Geiger, 1965).

The graphs illustrate the close correlation of Tauber's results with those expected for gravity settling in a smooth air flow. The results of the present series of experiments, although giving slightly higher efficiencies, confirm this trend. The scatter of points may be partly explained by the observation that rotorod spore catches tended to show non-random distribution of spore load along the collector. This suggests that spores were not sufficiently well dispersed: this would lead to increased errors in estimate of dosage from all traps.

iv) Collection efficiency for spores and pollen grains of different size

A mixture of Lycopodium spores and pollen grains of Tsuga canadensis, Pinus radiata and Ambrosia trifida was dispersed at a wind tunnel speed of 2 m/sec, with the three particle samplers in place as described previously. In this experiment no attempt was made to determine the absolute catch of particles of each type, but instead all samples were reduced by standard techniques to silicone oil suspensions, from which microscope slides were prepared. A slide of the original pollen and spore mixture was also made up by mixing a sample with silicone oil on a microscope slide and covering directly with a cover slip. The total number of pollen and spores of each type was counted for each trap slide by traversing the complete area under the cover slip. For the control sample fields were counted at random in the central part of the slide.

Table 2.1

Summary of Wind Tunnel Results

Run No.	Wind Speed (m/sec)	Dosage (grains/sq cm)			Efficiency	
		Rotorod	Filter	Tauber	from Rotorod	from Filter
1	1	260	*	33.4	.1285	*
3	3	2292	3666	46.5	.0203	.0127
4	4	3020	3245	44.0	.0146	.0136
5	5	1637	6010	8.9	.0054	.0015
6	6	6051	7452	13.2	.0022	.0018
7	7	2747	*	11.4	.0041	*
8	8	8054	5513	19.4	.0024	.0035
10	10	5210	10638	12.5	.0024	.0012
12	12	16790	14243	41.9	.0025	.0029
13	1	1883	2524	158.7	.0843	.0629
14	1	1234	3365	166.6	.1350	.0495
15	2	1813	1022	28.0	.0154	.0274
17	4	3830	*	27.6	.0072	*
18	5	*	5632	15.3	*	.0027
20	11	4298	8334	43.1	.0100	.0052

* Result suspect or missing.

Proportions of the pollen and spore types varied inconsistently between slides from the filter trap sample, possibly because of poor mixing. As there was little material left for preparation of further slides, the results of this trap were abandoned. Results for the other two traps are listed below, with that for the control sample.

	Rotorod	Tauber	Control
<u>Tsuga</u>	2	18	104
<u>Pinus</u>	2	27	102
<u>Lycopodium</u>	9	32	420
<u>Ambrosia</u>	33	20	1125
Totals	46	97	1751

Although counts for the trap samples are low, statistical tests are possible. Regarding the control sample as giving expected frequencies of the particle types, chi-square values for the Rotorod and Tauber trap results are 1.127 and 139.53 respectively. With 3 degrees of freedom, the Rotorod value fails to reach the 5% probability value of chi-square (in fact, $p = 0.77$), while the Tauber trap value has a probability close to zero. In other words, the Rotorod results cannot be regarded as significantly different from the expected values, while the Tauber results are clearly different.

Pollen and spores appear to have been dispersed in the wind tunnel in accordance with their proportions in the original mixture, since the Rotorod is believed to be an unbiased collector. Examination of the Tauber trap results shows that the larger (therefore presumably heavier) pollen types were caught in excess of the wind-tunnel proportions, while the smaller types were caught below their wind-tunnel proportions. Equating the efficiency of catch of Lycopodium spores to 1, Tsuga pollen was 2.3, Pinus 3.5 and Ambrosia 0.23.

If, as suggested in the preceding section, the Tauber trap is acting as a gravity settling device, relative efficiencies should be in the ratio of settling velocities. Reported settling velocities are for Ambrosia trifida 0.82 cm/sec (Durham, 1946) for Lycopodium 1.76 cm/sec (Geiger, 1965); no reported values were found for Tsuga canadensis or Pinus radiata but values of 2.5 to 5.3 are quoted for Pinus sylvestris (Durham, 1946; Dyakowska, 1936; Geiger, 1965). Using these values, catch efficiency of Pinus and Ambrosia relative to

Lycopodium should be 0.47 and 1.4 to 3.0 respectively.

Tsuga could be expected to have relative catch efficiency of about 2. While relative catch efficiencies observed are somewhat greater than predicted by settling velocities, in view of the small number of grains counted, and the single trial, the agreement is probably as good as could be expected.

Tauber dispersed mixtures of Lycopodium spores and pollen grains of Fagus sylvatica and Corylus avellana at various wind speeds. He found that at wind speeds less than 2 m/sec the larger Fagus pollen grains were caught with higher efficiency than Lycopodium spores, these in turn being caught more efficiently than Corylus grains. At wind speeds above 2 m/sec the reverse was the case. He suggests that

"... gravity settling is not of the same importance in the trapping procedure for small and large grains. For small grains vorticity at the interface between the moving air and the stagnant air in the trap appears to be a significant factor too. This vorticity will increase in magnitude with increasing wind velocity and thus will tend to counteract the strong fall in collection efficiency with increasing wind speed that would result, if gravity settling was the only factor of importance."

v) Conclusions

In conditions of smooth air flow and wind speed below 2 m/sec the Tauber trap appears to function essentially as a gravity settling device. Particle catches, when divided by orifice area, appeared to give a dosage per unit area in accord with theory. This was confirmed by Tauber who found, from tests on similar samplers with various orifice areas, that particle catch was directly proportional to orifice area. At higher wind speeds smaller pollen grains may be collected at higher rates than suggested by theory, although this was not confirmed in the present experiments.

Tauber found that the fitting of a circular metal 'umbrella' to exclude rain from the trap, did not affect the particle catch from a steady horizontal air stream. A cover of similar type, consisting of a flat PVC disc 50 cm in diameter supported by metal rods 15 cm above the trap orifice, was used for one of the traps in the present study.

Given a uniform concentration of particles in the air, the area dose rate is equal to the product of the concentration and wind speed. If the relationship

$$\text{trap dose} = \text{area dose} \times \frac{Vt}{V_0}$$

holds, then

$$\begin{aligned} \text{trap dose rate} &= \text{area dose rate} \times \frac{Vt}{V_0} \\ &= \text{concentration} \times Vt \end{aligned}$$

That is, the trap dose rate is proportional to the atmospheric concentration and the settling velocity of the particles concerned, but is independent of wind speed. Thus traps with different exposure to wind should yield the same particle catch in a given time. This will be examined in the light of present results in Chapter 4.

The relationship of the efficiency of the Tauber trap for various pollen and spore types to the efficiency of their collection by natural surfaces in the natural environment, where greater turbulence may be expected, also clearly requires investigation, but prima facie the device appears to be a suitable analogue.

Sampling

Field siting is discussed in Chapter 4. After exposure either the trap was replaced with a fresh one, or the top plate was removed and the contents washed out into plastic jars with copious quantities of water. In such a case the trap was then wiped out, washed, and recharged. Trap samples were either filtered in the field using membrane filter apparatus and a hand air pump, or returned to Canberra for processing.

FIELD COLLECTION OF SNOW SAMPLES

Snow cores were taken at sites, indicated in Chapter 4, with a Utah snow corer of cross-sectional area 11.40 sq. cm. Three cores were taken from each site, depth-equivalent segments from corresponding 76 cm long detachable core tube sections being aggregated in plastic bags. In some cases the lowermost samples were contaminated with soil or turf which could not be effectively separated from the snow sample.

After thawing of 1970 samples in the field hut, their volumes were measured before filtration through membrane filters. 1971 samples were stored for some time, during which water loss occurred through the plastic bags, so that measured volumes were not reliable.

The volumes of these samples were estimated from probable snow densities.

FIELD COLLECTION OF WATER SAMPLES

Water samples were collected from the main influent stream and from the lake surface near its efflux by immersing two litre capacity plastic bottles in the water.

Samples were later filtered through membrane filters and these stored until required for preparation.

LAKE SEDIMENT TRAPS

Initially an original design was tried which consisted of PVC plastic cylinders attached to 40 cm square iron plates. These were anchored on the lake floor by a concrete brick attached by a trace, the brick being buoyed at the surface. These failed for two reasons. Firstly it was uncertain how much of the trapped sediment was contributed by disturbance of the lake floor during the anchoring process. Secondly drag of the anchors, or the weight of the plates themselves, caused settling of the plates into the lake bed, and several of the traps could not be recovered.

A design described by Davis (1968) was then tried, and proved successful (see figure 2.4). The orifice diameters of the plastic trap jars used were 9.98 (10.12) 10.21 cm, the orifice areas 78.7 (80.4) 81.5 sq. cm. Jars were lifted into a boat at the surface for exchange with fresh jars, sample jars were then capped and the sample extracted on shore. Although slight disturbance of the sediment in the jars occurred during recovery, loss of sample is not believed to have been appreciable.

Upon return from the field, samples were reduced by filtration on membrane filters, sometimes a lengthy process.

Siting of traps is described in Chapter 4, together with results.

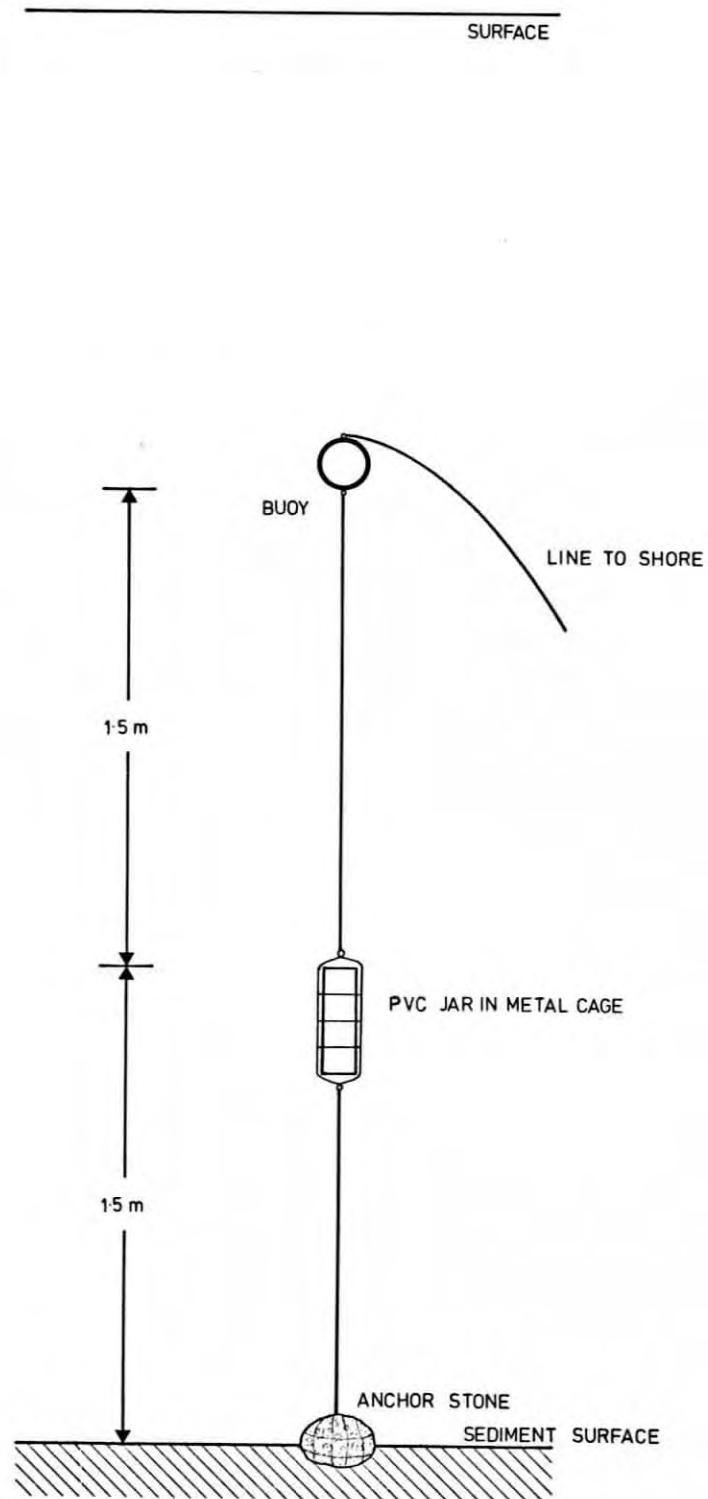


FIG. 2.4 LAKE SEDIMENT TRAP

SAMPLING OF SEDIMENT CORES

After return from the field, the plastic-film wrapped cores were stored in an air-conditioned high-humidity room until sampled. When sampling was done (at 90% relative humidity) no appreciable shrinkage in the cores had taken place, as judged by comparison of field and laboratory core lengths, hence no correction to volume of sample for shrinkage of core was made. Trial preparations showed that a 1 cc sample of core would provide adequate pollen recovery; this size of sample was convenient for processing.

An attempt was made to sample the cores with pharmaceutical gelatin capsules but these proved difficult to handle when wetted by the sediment, and dry weights of samples taken in this way had a standard deviation of over 5%. Variation in wet sediment sample weights was even greater, so this method was discarded.

Subsequently, samples were taken from the central part of 1 cm thick slices of core with a modified 1 ml plastic tuberculin syringe (see Plate 2.1, 2). The tip was ground off so that the orifice was of the same diameter as the barrel, and the orifice edges sharpened. The sampler was inserted into the core in the manner of a Livingstone sampler, i.e. by holding the piston at a constant height and pushing the barrel into the sediment. Several strokes were made to fill the sampler to an inscribed mark. The outer surface of the sampler was then wiped, the sample levelled at the open end, and the sample extruded into a tared vial.

Two series of samples taken with this sampler gave the following weights of wet sediment:

	No. of samples	Mean weight & standard deviation (g)	Maximum deviation
Blue Lake surface mud	10	1.235±0.007(0.6%)	1%
Blue Lake core 2, c.250 cm	5	1.132±0.002(0.2%)	0.3%

The effective volume of the sampler was determined by finding the density of the Blue Lake surface mud sampled in the above table and deriving the volume by the formula.

$$\text{volume} = \frac{\text{mean weight of samples}}{\text{density}}$$

The resulting volume was 0.943 ± 0.006 cc, the standard deviation being 0.6% of the mean.

All samples were tared and a duplicate was kept from each level sampled. The remainder of each 1 cm core slice was used to determine water and organic matter content of the sediment.

Twynam Cirque material was sampled in a similar way.

Bonny (1972) has described a method of volume measurement of samples wherein crumbs of sediment are added to a known volume of water in a narrow measuring cylinder until the desired sample volume is reached. This method appears to be of similar accuracy to that described above, and may yield more consistent results between operators. With practice, however, the method described above is likely to be quicker.

REDUCTION OF TRAP, SNOW AND WATER SAMPLES

Samples were sieved through 250μ stainless steel sieves and collected by filtration on 47 mm diameter cellulose ester Millipore membrane filters with a mean pore size of 8μ . Since the pore size of these filters varies only slightly ($\pm 1.4 \mu$ maximum deviation - Millipore, 1966), negligible pollen loss through the filters was expected, as no pollen smaller than 10μ was recognised in samples prepared from core material, which were not filtered. The apparatus used is illustrated in Plate 2.1, 1.

Samples on the filters were washed with alcohol while in the filtration apparatus, before being stored in vials until chemical preparation was convenient.

Filtration of samples was preferred to centrifugation in order to reduce losses due to decantation of floating pollen. Such losses are more likely with modern than with fossil pollen, because of the lower density of oils and protoplasm associated with the modern pollen (e.g. Matthews (1969) found that modern Liquidambar pollen did not settle in aqueous suspension under centrifugation).

Attempts were made to complete chemical preparation in the filter apparatus, but trial samples could not be properly dispersed even with prolonged ultrasonic treatment.

CHEMICAL PREPARATION

Procedure

Preparation of lake sediment samples followed the following schedule. Centrifugation and decantation of unwanted liquid followed each step.

1. Samples were washed from storage vials through sieves of mesh size 250 μ into round base polythene centrifuge tubes, with distilled water. Sieve residues were stored for later analysis.
2. Fifteen ml of 40% hydrofluoric acid aqueous solution was added to each sample to remove silica and silicates, and the samples left at least 24 hours.
3. Warm 10% hydrochloric acid was added to remove acid-soluble fluorides.
4. The samples were transferred to conical-base glass centrifuge tubes with distilled water washings.
5. Samples were dehydrated with two washings of concentrated acetic acid.
6. Erdtman's acetylation to remove cellulosic materials was carried out with a mixture of 9 parts of acetic anhydride and 1 part of concentrated sulphuric acid, for 10 minutes at a maximum temperature of 100°C.
7. Samples were washed with concentrated acetic acid to remove soluble organic materials.
8. This was followed by an ethanol wash to remove acetic acid.

After decantation of the ethanol wash the samples were made up to a known volume with tertiary butyl alcohol (TBA). This was done in a small volumetric flask, by washing in the sample with TBA and making up the volume to the graduated mark. If further dilution was required, a sample was withdrawn from the thoroughly agitated primary suspension with an adjustable automatic syringe (Manostat Mini-Pet) and delivered to a volumetric flask, where its volume was made up with TBA as before. TBA suspensions were stored in small conical flasks or glass vials, in which they were given short ultrasonic treatment to aid dispersion.

Filters retaining lake sediment trap samples were dissolved in concentrated acetic acid and the procedure for lake sediments followed from step 2, above. For aerial pollen trap, snow and water samples, filters were similarly dissolved and the procedure followed from step 5.

Estimation of losses during chemical preparation

Chemical preparation was reduced to as few steps as possible to reduce losses due to decantation of sample material.

An estimate of decantation losses was made in the following way. Four 1 cc samples of Blue Lake surface mud were processed (without hydrofluoric acid treatment as this produced insoluble gels which interfered with slide examination). The decanted liquids from each sample were collected in large volumes of distilled water. These volumes were filtered through Millipore filters which were then dissolved in concentrated acetic acid in centrifuge tubes. The loss samples were then washed with further acetic acid, then ethanol, and suspended in TBA. Aliquot slides were made up from each preparation and total pollen count (excluding algal spores, etc.) estimated for each. Observation suggested that losses from these samples were less than those from the original preparations which provided them. Counts from aliquot slides each representing 1/50 of the relevant loss sample preparation are listed below.

Preparation 1	Poaceae 1, <u>Callitris</u> 1
" 2	Poaceae 2, Other 1
" 3	Poaceae 4
" 4	0

Thus only 9 grains were counted, giving mean loss sample total of $9 \times 50/4 = 113$ grains. An aliquot slide prepared from a suspension of one of the original samples (LMD 1) gave a total pollen count of 355000 ± 19000 grains. Thus decantation losses were extremely small in this series of preparations, being of the order of 0.03%.

PREPARATION OF SLIDES

Benninghoff (1962) has given a brief description of a method for estimation of the absolute frequency of fossil pollen in a sample by the addition of an estimated number of pollen grains of an exotic species. Both fossil and exotic

pollen are counted and the number of fossil pollen per sample is given by $A \times B/C$ where A is the number of exotic grains added, B the number of fossil grains observed and C the number of exotic grains observed. Matthews (1969) and Bonny (1972) have elaborated on the method. Although simple in principle, it introduces uncertainty in the estimation of frequency of fossil pollen which may be greater than in methods based on volume or weight of sample counted (Davis, 1965, 1966; Jørgensen, 1967). This uncertainty is due to sampling error in addition of exotic pollen (i.e. in A) and to the variation to be expected in the observed proportions of taxa (B/C) due to chance. To minimize these errors large counts and careful standardisation of exotic pollen preparations are necessary. The method can, however, provide an automatic correction for loss of sample during preparation, if the exotic pollen is added at the outset, and if this pollen behaves in the same manner as the fossil pollen.

Because of the uncertainties associated with the exotic pollen addition technique, the aliquot method of Davis (as modified in 1966) was used. Sampling of the thoroughly agitated TBA pollen suspension was done with an Oxford Micro Pipetter illustrated in Plate 2.1, figure 2. This device uses disposable tips of a plastic material whose tendency to retain an inner surface film is less than glass. The danger of cross-contamination of samples at this stage is thus eliminated and error due to retention of liquid minimized. The volume of nominal 0.2 ml aliquots from the sampler was determined by weighing 10 aliquots of TBA taken with different tips, converting these weights to volumes using a determined density for the TBA used. Mean volume was 0.2000 ml, standard deviation 0.0026 ml (1.3% of mean) and range 0.1941 - 0.2028 ml (- 3.0% + 1.4%).

In slide preparation a small quantity of silicone oil (Wacker, AK 2000) was placed on a slide heated on a hotplate. An aliquot (sometimes more than one) of pollen suspension was deposited dropwise onto the silicone oil and allowed to evaporate thoroughly. The slide was then provided with a 19 mm square cover slip and sealed with clear nail varnish which allowed the total aliquot to be counted.

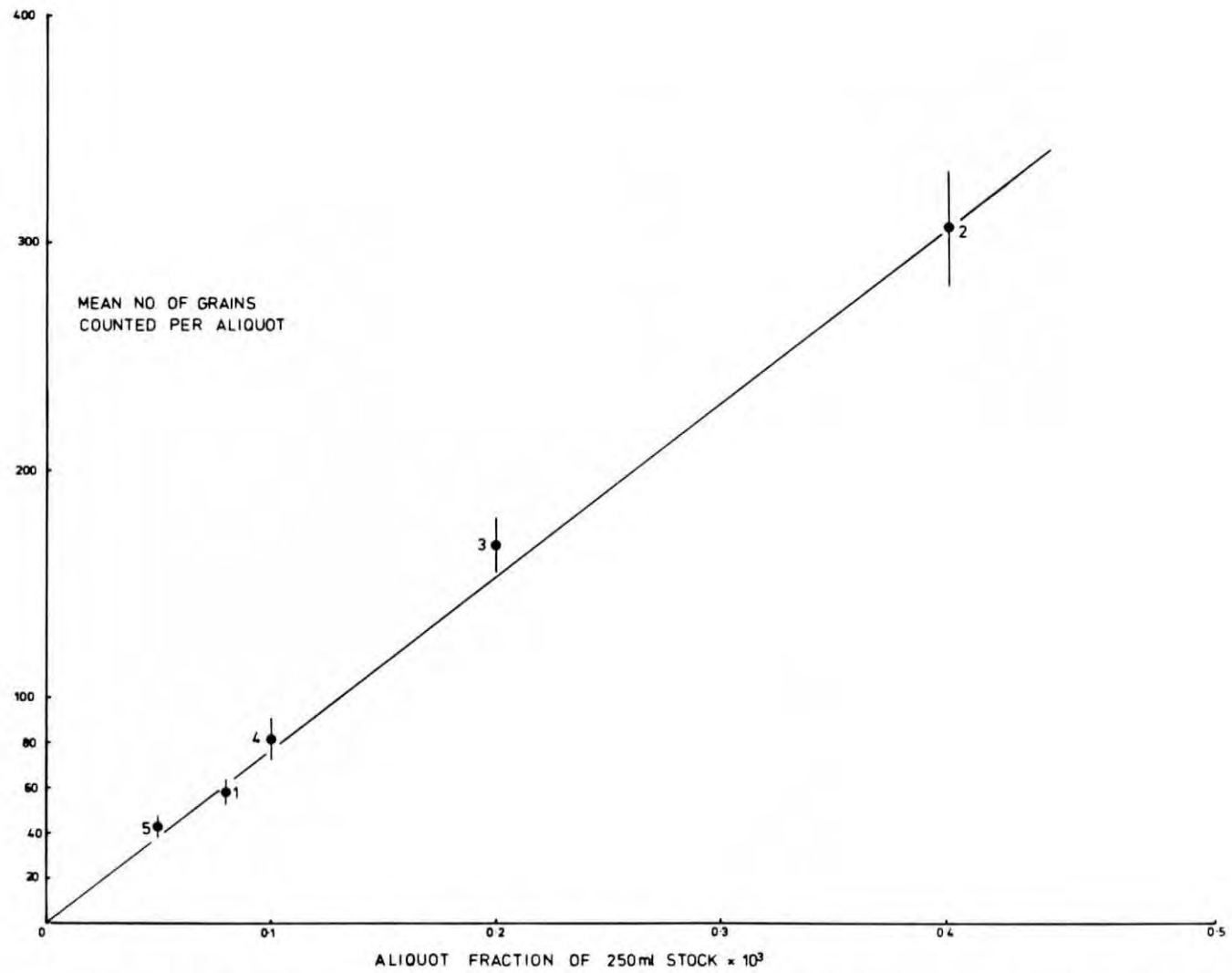


FIG. 2.5 TSUGA POLLEN GRAINS COUNTED PER ALIQUOT AS A FUNCTION OF THE FRACTION OF THE STOCK SUSPENSION REPRESENTED BY EACH ALIQUOT

In order to test the reproducibility of pollen counts from slides made in this way, the method of Davis (1965) was followed. A suspension of Tsuga canadensis pollen was made up and serially diluted using a syringe to provide suspensions of 1/2, 1/4, 1/8 and 1/16 of the original concentration. Series of slides were prepared from each of these suspensions by withdrawing aliquots while the samples were being stirred with a magnetic 'flea', and proceeding as above. The original suspension was sampled with a 0.02 ml sampler of similar type.

Figure 2.5 illustrates the results of the slide counts. Vertical bars show one standard deviation about the mean, represented by solid circles. The linear correlation coefficient for the data pairs (mean number counted: fraction of original suspension) is 0.998. Thus the number of pollen grains counted is directly proportional to the fraction of original suspension prepared.

Table 2.2 is derived from the same data. For each series of slides, the variance in observed Tsuga pollen counts, S^2 , approximates the mean number of grains counted, \bar{X} , as would be expected for a Poisson distribution of counts. Deviation of observed variance from the expected variance of a Poisson distribution may be tested by computing for each series

$$\chi^2 = \frac{\sum_{i=1}^N (X_i - \bar{X})^2}{\bar{X}}$$

which is approximately chi-square distributed (Cochran, 1954). In no case was there reason to reject the hypothesis that the differences are due to chance (since the probability, p , was always below the 95% level), so that a Poisson distribution may be assumed.

To test for loss of pollen grains due to adherence to the inside of pipette tips, a series of pipettings was carried out with a suspension of Tsuga pollen containing an estimated 612 grains per 0.2 ml aliquot. The number of grains adhering to the inside surface of each pipette tip was counted under a stereomicroscope. From observation of 10 tips, the mean number of grains retained was 22.9 (3.7% of the number in the aliquot), the range 18-36 (2.9 - 5.9% of aliquot number) and standard deviation 5.7 (0.9%).

Table 2.2

Variance observed in counts of replicate aliquot slides prepared from suspension of Tsuga pollen, and chi-square tests thereon.

No. of aliquot slides counted	Mean number of grains counted per slide	Range	Variance	χ^2	p	
5	58.4	51-65	24.8	1.698	0.209 (4 degrees of freedom)	
5	306.6	284-348	636.7	8.308	0.919 (d.f. = 4)	
10	167.3	151-188	139.6	7.496	0.414 (d.f. = 9)	
10	81.3	71-97	89.6	9.915	0.643 (d.f. = 9)	
10	43.1	33-51	28.1	6.517	0.313 (d.f. = 9)	
				TOTAL	33.934	0.300 (d.f. = 39)

COUNTING METHODS

Routine counting and identification of pollen and spore grains was done using a Carl Zeiss (Oberkochen) Universal Photomicroscope.

Since it could not be expected that pollen grains were randomly spread on a slide, wherever possible the entire area under the cover glass was scanned by moving the slide in an E-W direction (parallel to the long edge of slide) from N to S (S being nearest the microscopist). At the completion of each traverse the microscope stage was advanced by observing a fixed particle on the slide at the lower limit of the eyepiece scale line and moving the stage so that this particle appeared at the upper scale limit.

During scanning, usually at a total magnification of 400 x, grains whose entire image passed through the N-S eyepiece scale line or which overlapped the lower limit of the line were counted. Grains overlapping the upper limit of the line were not counted, so that no grain would be counted more than once. It is believed that this method avoids the problem of grains appearing partially at the edges of the field of view, such grains being less likely to be counted during a traverse because they appear very briefly (Jørgensen, 1967), or necessitating a movement of the stage from the traverse line for identification.

Suspension concentrations were adjusted on the basis of preliminary slide examination, to yield slides containing 100-300 pollen and spore grains. Slides of pollen trap material sometimes fell below this concentration.

Additional slides were not made if calculation showed that the contribution of these trap periods to the annual trap collection was small, because of lack of time. If a slide contained too many pollen grains for convenient counting, regularly spaced traverses were made with the microscope, and the counted aliquot fraction adjusted to

$$\frac{\text{no. of traverses} \times \text{N-S width of traverse}}{\text{N-S width of slide}}$$

Since clumping of pollen grains and debris appeared to have been successfully prevented by the ultrasonic treatment mentioned previously, errors in the traverse technique of estimation of pollen count are probably mainly due to irregular

distribution of individual pollen on the slide. No measurements of this type of error were made, but it is believed to be not greater than 20% of the true pollen count. Samples involved, mainly from lake sediment traps, snow cores, and the Twynam Cirque section, are indicated in the tables in Appendix D.

Counts were marked on standard forms, and the totals later written onto summary sheets from which computer punch-card forms were prepared. Punched cards were used to create magnetically recorded data files at the ANU Computer Centre's UNIVAC 1108 site. Further manipulation of these data files was by use of system programmes or those written by the author and presented in Appendix B.

IDENTIFICATION OF POLLEN AND SPORES

Identification of unknown grains was made under an oil immersion objective at a total magnification of 1600 x. Identification was assisted by use of the computer matching program described by Walker *et al* (1968) as a guide to the extensive reference collection of modern pollen slides held in the Department of Biogeography and Geomorphology. This collection was augmented by the author, during the course of the study, by addition of herbarium and fresh material from the Snowy Mountains region.

A key formalising the results of work on the Snowy Mountains material is presented in Appendix A. Photographs making up the plates were accumulated during the course of the study and associated code-numbers used to label unknown pollen or spore types until identification. The notation of Benninghoff and Kapp (1962) is used to denote degree of uncertainty of identification, except that those types remaining unidentified at the conclusion of the study were grouped as 'Unknown' while grains not sufficiently well preserved to identify were grouped as 'Unidentifiable'.

Various subjective factors enter to distort the observed pollen and spore counts from the true ones. These include

- i) Failure to recognize particles as pollen or spore types
- ii) Assignment of grains to the wrong category
- iii) Missing poorly preserved grains
- iv) Missing small, though well-preserved, grains

Type i) errors were probably more frequent at the beginning of the study, affecting mainly Blue Lake core 1 samples. After a few samples were examined, it is probable that this error did not exclude any pollen or spore type eventually observed, although certain pollen or spore types could conceivably not have been recognized.

Type ii) errors were also more frequent in the initial stages of the study. Use of code-numbers rather than plant names reduced this error, but some re-assignments were necessary. Errors remain, mostly involving the assignment of rare pollen or spore types to some more common category. For example, Melaleuca pollen grains may have been assigned to Eucalyptus, Podocarpus to Pinus, Hibbertia to Cruciferae. The effect is to slightly increase the frequency of the common types at the expense of rare types. Some rare types may have remained unrecognised through confusion with a common type, e.g. Logania pollen was not recognised, although the plant occurs in the Geehi area. The pollen may have been included with that of Pomaderris.

Type iii) errors especially affect those taxa with pollen grains of simple morphology and thin exine. Thus Cyperaceae, Restionaceae, Urticaceae and Callitris pollen frequencies may have been underestimated. The errors in observed frequencies of these taxa will also be greater, because preservation varies from one preparation to another, even though the same chemical preparation technique may have been used.

Type iv) errors, due to oversight of small grains during scanning, mainly affect pollen and spore types with a maximum diameter of less than 15 μ . These include Urticaceae, Utricularia, some Asteraceae, Bursaria spinosa, Daviesia, Hypericum and Leptospermum.

A further minor difficulty in calculation of pollen frequencies is the occurrence of certain pollen types as polyads or tetrads, or as single grains. Acacia pollen occurred as 16-grain polyads and singly. The number of single grains was divided by 16, rounded up to the nearest integer and added to the number of polyads observed, to give the observed frequency of Acacia pollen for a slide. This procedure probably slightly overestimates the frequency of Acacia pollen,

depending on the state of disaggregation, but since this is a minor pollen type, errors are not of great significance. Epilobium pollen frequencies were adjusted similarly, for an aggregate number of 4 grains; gymnosperm pollen frequencies were adjusted to the greater of the sum of whole pollen plus corpi or the number of discrete sacci divided by two.

ESTIMATION OF POLLEN FREQUENCY

The total number of pollen grains in the original sample was calculated using the following formula:

$$\begin{aligned} \text{Total number} = & \text{Aliquot count} \times \text{fraction of aliquot} \\ & \text{counted} \times \text{number of aliquots in} \\ & \text{diluted suspension} \times \text{number of dilution} \\ & \text{samples in total original suspension} \end{aligned}$$

Frequency of pollen grains per unit volume, weight, or area was then calculated by applying the appropriate correction factors.

Since, as has been shown, the numbers of pollen grains or spores counted in aliquots of the same size may be regarded as having a Poisson distribution, the expected standard deviation associated with a universe of such samples is equal to the square root of the mean number. For a single estimate, the standard error of estimate is equal to the population standard deviation. Thus, for a count of 100 grains, the standard error of estimate would be 10 grains (10%). The true (population) count for an aliquot of the same volume should be within the range 100 ± 10 grains 68% of the time, and within the range 100 ± 20 grains 95% of the time. It is clear that in improving the precision of estimation of true frequency, a law of diminishing returns applies:

for 10 grains counted,	standard error of estimate is 3.2 grains	(32%)
for 100 " " " " " "	" 10 "	(10%)
for 1000 " " " " " "	" 32 "	(3.2%)

Precision of estimation of the pollen content of a sample is also affected by errors attached to measurement of sample and aliquot volumes and dilution factors and by varying losses during sampling and preparation.

Systematic errors in measurement of sample and slide aliquot volumes are believed to be negligible, as these volumes were determined by measurement of mass with an accurate balance. The accuracy of measurement of vessels used in dilution of pollen suspensions was not determined, but is believed to be high, because of the linearity of aliquot-count/aliquot-fraction determinations on Tsuga pollen suspensions described previously.

Loss of sample during preparation is likely to be the greatest contribution to systematic error in the laboratory procedure. Routine addition of measured quantities of Tsuga pollen for the purpose of detecting losses failed because insufficient was added and because ultrasonic treatment destroyed or damaged a variable proportion of Tsuga grains, up to about 50%. (Other pollen types apparently affected were Neopaxia and Pinus. Small grains, e.g. Eucalyptus, did not appear to be affected by ultrasonic treatment).

To help correct this deficiency, a series of slides was prepared from the contents of four unexposed Tauber traps, to each of which measured quantities of Tsuga pollen suspension had been added. These trap samples were prepared in the usual way, so that any losses detected would be the sum of extraction plus chemical processing losses, but would not include losses in slide preparation, as the concentration of the added suspension was determined from similar slides. The expected slide count was 128.3 ± 8.5 grains. Results were as follows:

Trap No.	Slide Counts	Mean	χ^2
1	115, 141, 127, 149	133.0	6.00
2	139, 140, 123, 118	130.0	3.01
3	102, 102, 99, 110	103.3	20.08
4	129, 139, 115, 124	126.8	2.42

Chi-square values were calculated using the expected frequency of 128.3. Chi-square for 4 degrees of freedom and 5% probability is 9.49: only the chi-square value for series 3 exceeds this value, and thus has less than 5% chance of occurrence by chance. In this case the best estimate of loss is $(128.3 - 103.3)/128.3$, or 19.5%, although, because of the uncertainty attached to the expected frequency, the loss may be less than this. In summary, it may be said that losses of the order of 20% may occur about once in every 4 times, but

that usually losses are very low, so that the mean loss is of the order of 5%. Observation suggests that most of this loss is due to retention of pollen grains in traps, since it is believed that retention on the walls of processing vessels is of the same low order as loss through decantation.

Because of the occurrence of occasional high losses, not always detected, too much reliance should not be placed on individual sample results, although, as will be shown in succeeding chapters, there is a good correlation between pollen frequencies determined from sediment samples of equivalent location.

Table 2.3 summarises the precision and accuracy of the various laboratory procedures discussed in the present and preceding sections. In addition to the uncertainty in estimation of pollen frequency due to the sampling procedure, and dependent only on total number of grains of the particular pollen type counted, an uncertainty of approximately 10% must be assigned to trap samples (coefficient of variation), and approximately 3% to sediment core samples from Blue Lake. This has been done in Appendix D tables.

Loss of material from modern pollen samples is of the order of 10%, while from Blue Lake core samples it is about 5%. No corrections have been made in the tables or diagrams for loss, this being considered in the synthesis of results.

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Table 2.3 Summary of Precision and Accuracy of Pollen
Frequency Estimation

<u>Procedure</u>	<u>Precision</u>	<u>Accuracy</u>
Extraction from trap	About 10%	4.9% loss
Extraction from core	0.6%	± 0.6%
Chemical Processing	0.06%	0.03% loss in decantation. Retention loss unknown, probably of similar magnitude.
Ultrasonic treatment	-	Loss of some large grains, e.g. <u>Tsuga</u> , up to 50%.
Dilution	Not measured, believed to be high (~1%)	Believed to be high (<1% loss)
Aliquot Sampling	1.3% in volume measure, 0.9% pipette retention	3.7% loss (<u>Tsuga</u>)
Scanning of Slide	Whole slide: high (~1%) spaced traverses: 20%?	Slight loss because of poor visibility at edge of cover slip (~1%)
Counting	$\sqrt{\text{no. counted}}$, from Poisson distribution	Dependent on pollen or spore type - see previous section.
<hr/>		
Sub-total: for modern samples	~10%	~10%
for Blue Lake cores	~3%	~5%
Counting	$\sqrt{\text{no. counted}, N}$ from Poisson distribution	Dependent on pollen or spore type - see previous section.
<hr/>		
Total: for modern samples	$100\sqrt{.01 + \frac{1}{N}} \%$	
for Blue Lake cores	$100\sqrt{.0009 + \frac{1}{N}} \%$	

Plate 2.1 Pollen sample preparation and wind-tunnel experiments

Legend

1. Membrane filter holder and conical stainless steel mesh sieve used for trap sample preparation.
2. a) Micropipette with disposable tip used for slide preparation.
b) Modified plastic syringe used for sediment sampling.
3. Smooth airflow over Tauber trap shown by smoke traces in wind tunnel (wind speed 2 m/sec).
4. Experimental setup for comparison of particle samplers at various wind speeds. Wind flow (from left to right) was controlled by shutters at right (seen closed in figure 6). The air pump, vacuum reservoir and valve below provided regulated suction for the isokinetic filter sampler.
5. Pollen was dispersed from a reversed vacuum cleaner blower via a funnel fitted with baffles to promote turbulent mixing, towards the honeycomb flow straightener at the induction end of the tunnel (at right).
6. View of samplers in tunnel, viewed from up-wind side.
 - a) Rotorod sampler
 - b) Isokinetic filter sampler
 - c) Tauber trap

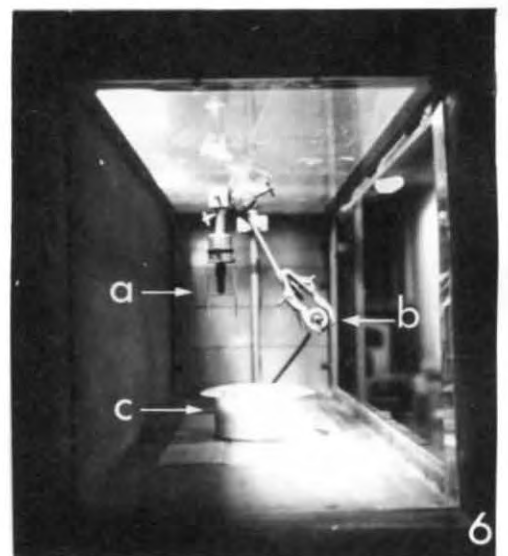
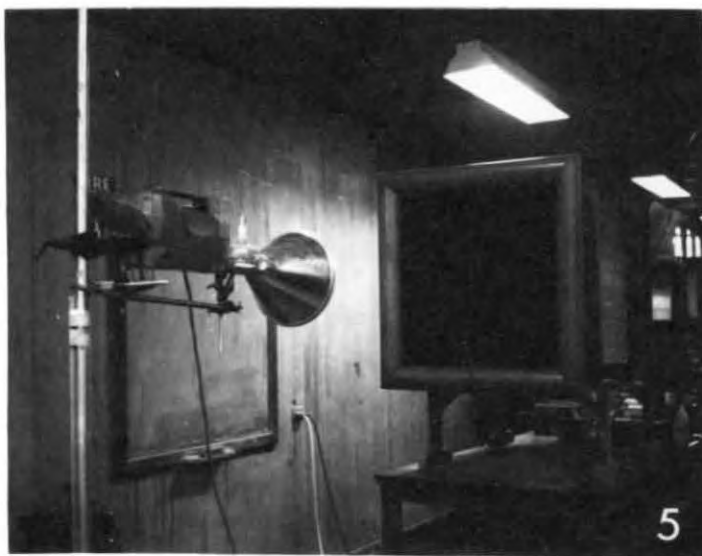
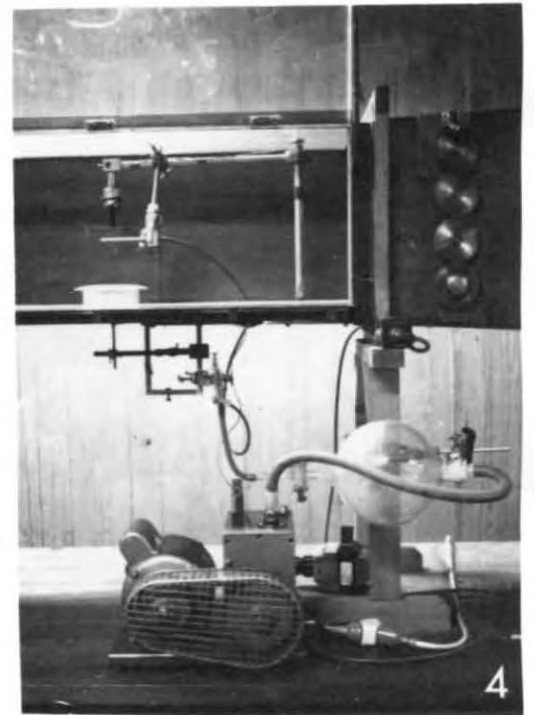
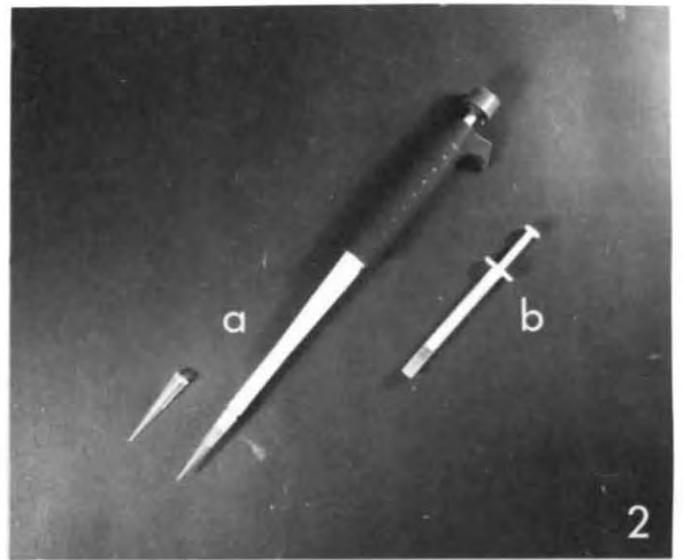
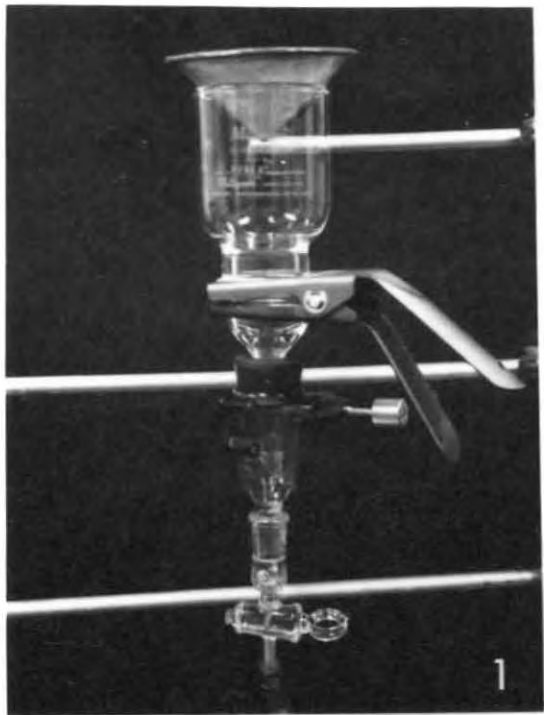


PLATE 2.1

CHAPTER 3

PALAEOPALYNOLOGY

BLUE LAKEMorphology

A survey of the lake bathymmetry was made by traversing with an echo-sounder attached to an inflatable boat. The boat was hauled by hand along ropes fixed across the lake; buoys at regular intervals along the ropes provided control points for drawing a bathymetric map, which is presented in figure 3.1. Eighteen continuous traverses made possible a map more detailed than that of Dulhunty (1945). Distinction could also be made between smooth lake bed, consisting of fine-grained sediment, and rough, rocky bed.

The map and sections of figures 3.1 and 3.2 show that the lake is roughly trapezoidal in shape, 540 m long by 360 m wide, and that the bottom is irregular, possessing depressions in the northern corner, and near the centre and the south-eastern end, 4 m, 26 m and 28 m deep, respectively. A northward-trending bedrock ridge on the south-western side can be seen to extend below waterlevel to a depth of about 12 m where it loses its identity. To the west of this feature is situated the delta of the largest influent stream. Here, as seen in section A-B, the bottom slopes gently to 2 m, more steeply to 10 m, then again gently to 14 m, where it steepens again. It seems likely that the gentle slopes between 10 and 14 metres depth are due to the presence of a bedrock shelf, represented further south by a marginal ridge, rather than to infill by deltaic sediments. This is confirmed by the relatively thin sequence of sediments in core 7, if the correlation indicated in fig. 3.3 is correct.

Progressing clockwise around the lake, steep slopes above the shore appear to continue below water level. In the northern corner of the lake a rocky barrier encloses the small basin previously mentioned. This appears to be a moraine formed by sliding of blocks down the surface of a south-east facing snowpatch or small glacier. It is possible that this process continues to the present day (Costin *et al.*, 1964).

On the north-eastern side of the lake bottom slopes are uniformly steep, the small delta of the stream entering

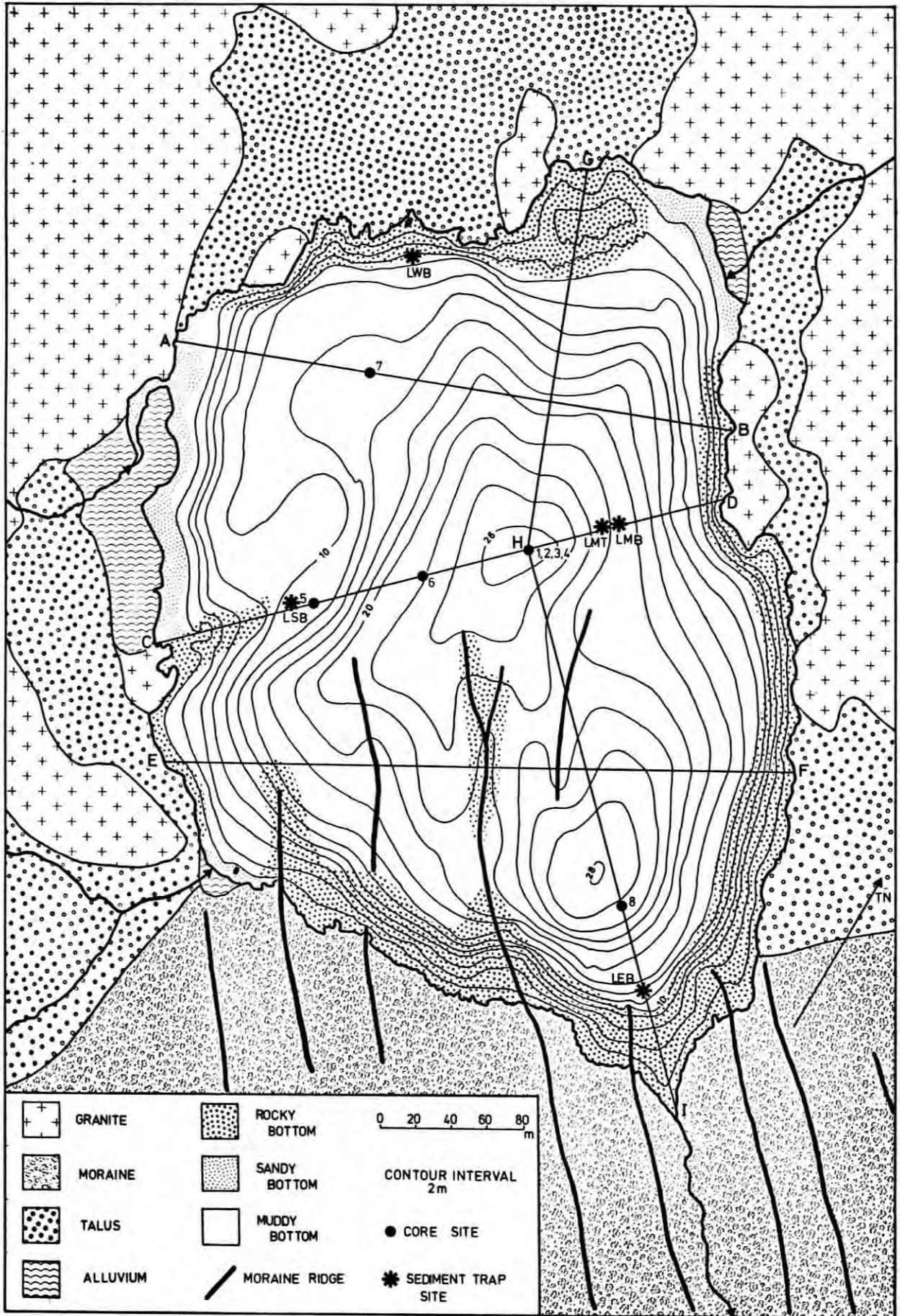


FIG. 3.1 BLUE LAKE

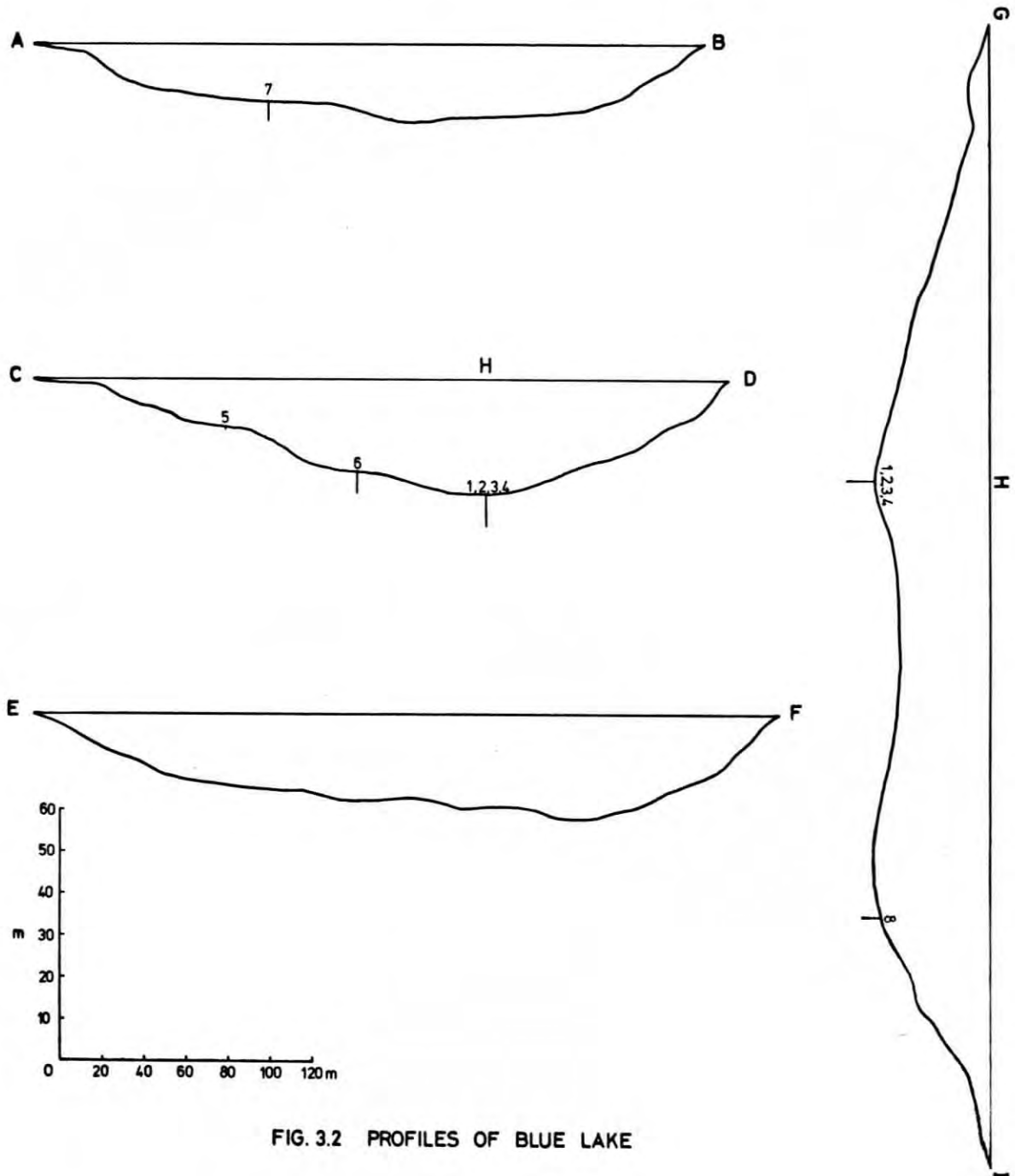
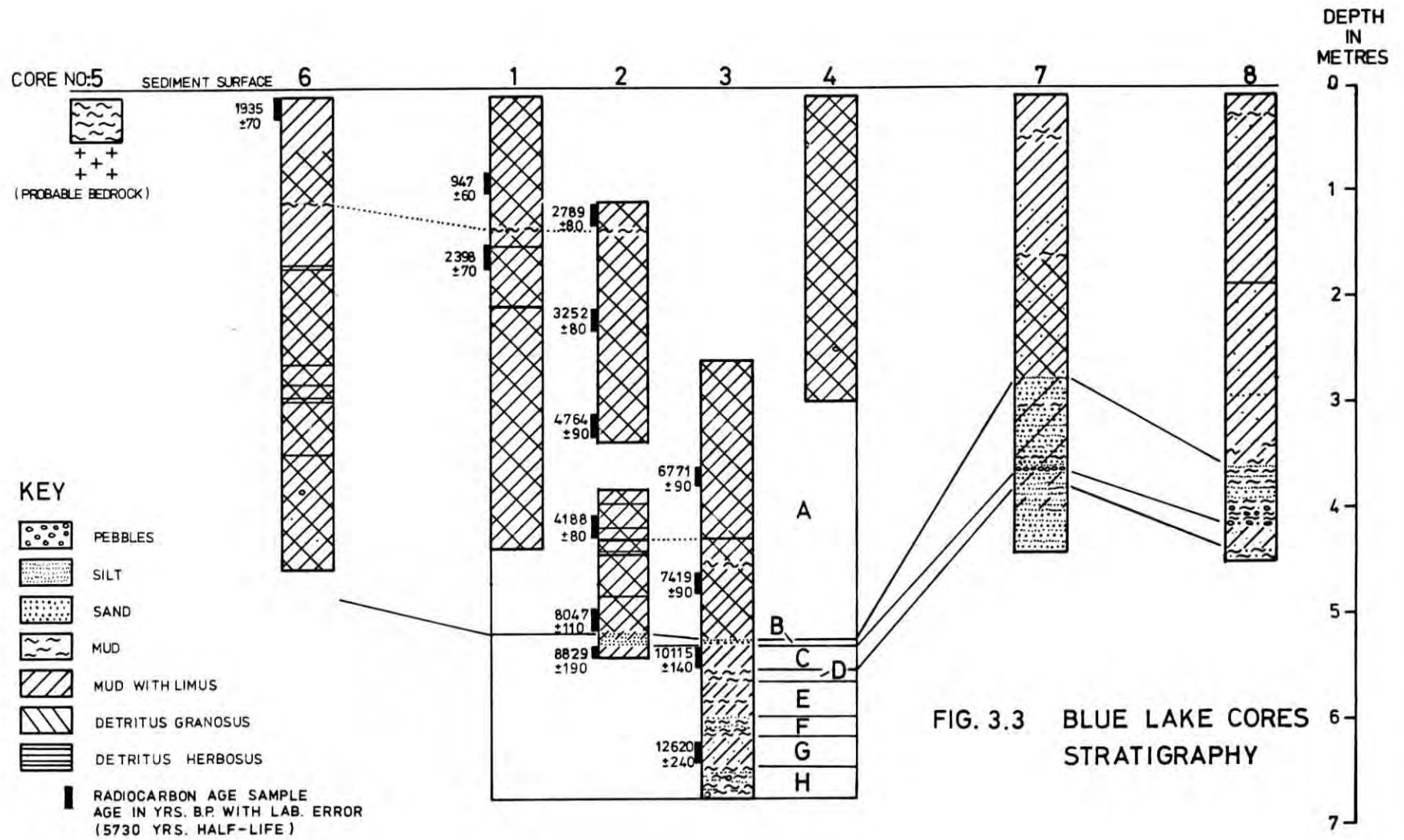


FIG. 3.2 PROFILES OF BLUE LAKE



near the northern corner apparently having little below-water extent.

As discussed by Dulhunty (1945), the lake is dammed only in part by moraine. Granite outcrops in the bed of the efflux creek about 50 m downstream from the lake and 5 m below its surface. Thus the lake originated principally through glacial overdeepening of the valley floor. The moraine, at the dam, consists of five ridges running north-west and south-east parallel to the main trend of the valley, but perpendicular to the general trend of the moraine as a whole. These ridges extend below the present shoreline, their extent being indicated in figure 3.1. The rise which separates the two main sub-basins of the lake also bears ridges with a similar orientation. As suggested by Dulhunty, it is likely that the ridges on the moraine dam, and those now distinguished at greater depth on the lake floor, are due to medial-morainic material resulting from the confluence of glaciers from the Crummer Range, Upper Blue Lake Cirque, and the valley to the south of the lake.

Except where the shoreline is composed of deltaic sediments, the lake bed is rocky to at least 7 m water depth, probably because of scouring by the winter ice and snow cover. Usually this reaches a thickness of about 3 m, but 7 m could be expected in an exceptional year of heavy snowfall. Lake ice has also packed firm the cobble beaches around the lake.

Stratigraphy

Core sites (see fig. 3.1) were selected after examination of preliminary bathymetric results with the following considerations:

- 1) To give a general picture of the lake sediment stratigraphy to aid selection of a pollen analysis core.
- 2) To provide a suitable core for pollen analysis.
- 3) To give the opportunity of comparison of fossil pollen spectra from various cores with those from sediment traps located nearby.

Choice of a suitable descriptive classification for sediments which consist of a mixture of terrigenous (inorganic) and organic material is a problem. Troels-Smith (1955) devised a comprehensive terminology for unconsolidated sediments. His scheme in part duplicated the Udden/Wentworth scale for

terrigenous sediments, and unlike this earlier scheme, widely used by sedimentologists, did not allow for mixtures of different-sized material. His detailed classification of organic sediments does not appear to have a parallel in the English-speaking world, however. The defect, again, is that no allowance seems to have been made for mixtures of organic and terrigenous material. The occurrence of various imprecise older terms, such as gyttja and its equivalents nekron mud (Godwin, 1938) and copropel (Swain and Prokopovich, 1954) and the complementary dy (gel-mud or sapropel) complicates the picture. For the present description the Udden/Wentworth terms used by Folk (1965) for mixtures of gravel, sand and mud have been used in conjunction with those of Troels-Smith for the organic fraction of the sediments, the word 'with' being used to connote an intimate mixture of the two components.

Basic terms are the following:

<u>Terrigenous Fraction</u>	Gravel: mean particle size more than 2 mm
	Sand: 0.0625 - 2 mm
	Silt: 0.0039 - 0.0625 mm
	Clay: less than 0.0039 mm
	Mud: a mixture of silt and clay
<u>Organic Fraction</u>	Detritus lignosus and Detritus herbosus: fragments of wood and herbaceous material, respectively, greater than 2 mm in size
	Detritus granosus: particles 0.1 - 2 mm
	Limus: fragments less than 0.1 mm diameter, plus humic colloids

Details of core stratigraphy are indicated in figure 3.3. At the central lake site, cores 1-4 were taken within a few metres of each other, as described in Chapter 2. Core 1 is correlated with core 2 by the common occurrence of a pale brown mud band at about 140 cm depth. This band also occurs in core 6, and is easily distinguished from the adjacent dark brown, more organic-rich, mud. Core 2 is correlated with core 3 by the set of sandy layers, unit B, and a prominent detritus herbosus band at about 430 cm depth.

Correlation of cores 1 and 3 was checked by application of the program CORRIE (see Appendix B) to

preliminary pollen counts from samples at 20 cm intervals through each core. This program first computed a mean dissimilarity measure (actually an information statistic) for comparisons between equivalent-numbered samples from each core (the 1st sample of core 1 compared with the first sample of core 3, the 2nd samples also compared, and so on), then stepped the core 3 samples down a level, so that the 1st sample of core 1 was compared with no sample, the 2nd sample of core 1 was compared with the 1st sample of core 2, and so on. This process was repeated until all possible correlations of samples had been tried, when the program stops. Figure 3.4 is derived from output from the program, and shows that the minimum mean dissimilarity occurs when the 1st sample of core 3 (core depth 0-1 cm) is matched with the 13th sample of core 1 (true depth 249-250 cm). This result compared well with that expected from sediment stratigraphy, and a depth of 260 cm for the top of core 3 was chosen as the best compromise figure. A comparison of total pollen content of the same samples confirmed the correlation (see Pollen Deposition Rate, this Chapter), as also did the radiocarbon sample ages, in a more approximate way.

The following description refers primarily to cores 1-3, but the other cores will be remarked upon where necessary. Results of tests on samples from cores 1 and 3 are indicated graphically in figure 3.5:

% water content of samples taken from the same level as pollen preparation material, % oxidisable organic matter from the same samples, relative amounts of organic fragments and mineral particles larger than 250 μ (medium sand size and above) from pollen sample sieve residues, and absolute numbers of pollen grains per gram weight of dry sediment and per cubic centimetre of fresh sediment. For convenience in description, several units have been recognized.

Unit A (0-524 cm) consists of brownish black mud (Munsell colour 10 YR 2/2 to 3/2), slightly sandy in the intervals 80-120 cm, 180-200 cm and 480-524 cm, with an admixture of limus and some coarser organic material, generally no coarser than detritus granosus. Arthropod remains form a prominent part of this organic fraction, together with fibrous herbaceous plant material, charcoal, and some woody fragments,

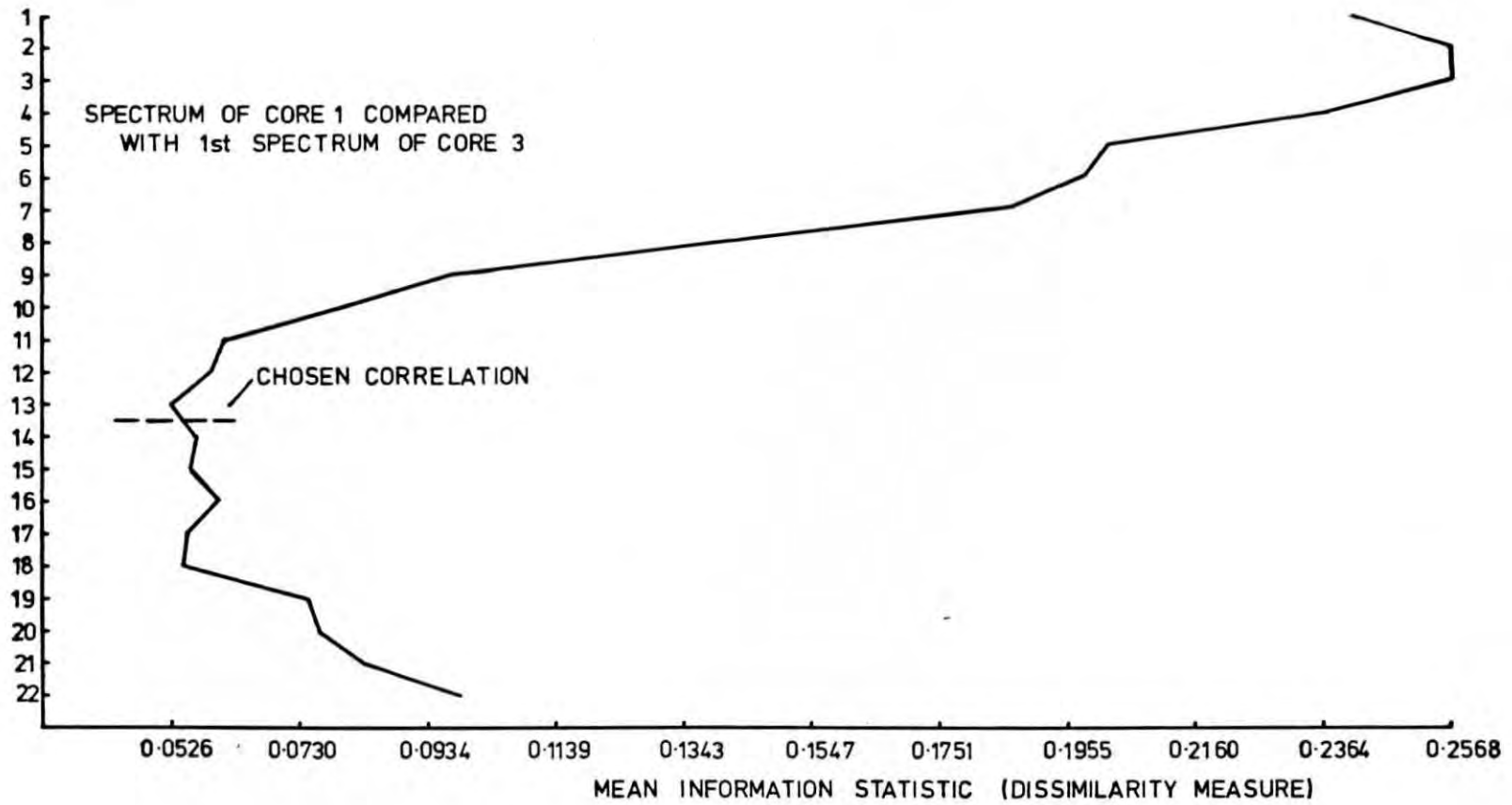


FIG. 3.4 CORRELATION OF POLLEN SPECTRA FROM CORES 1&3

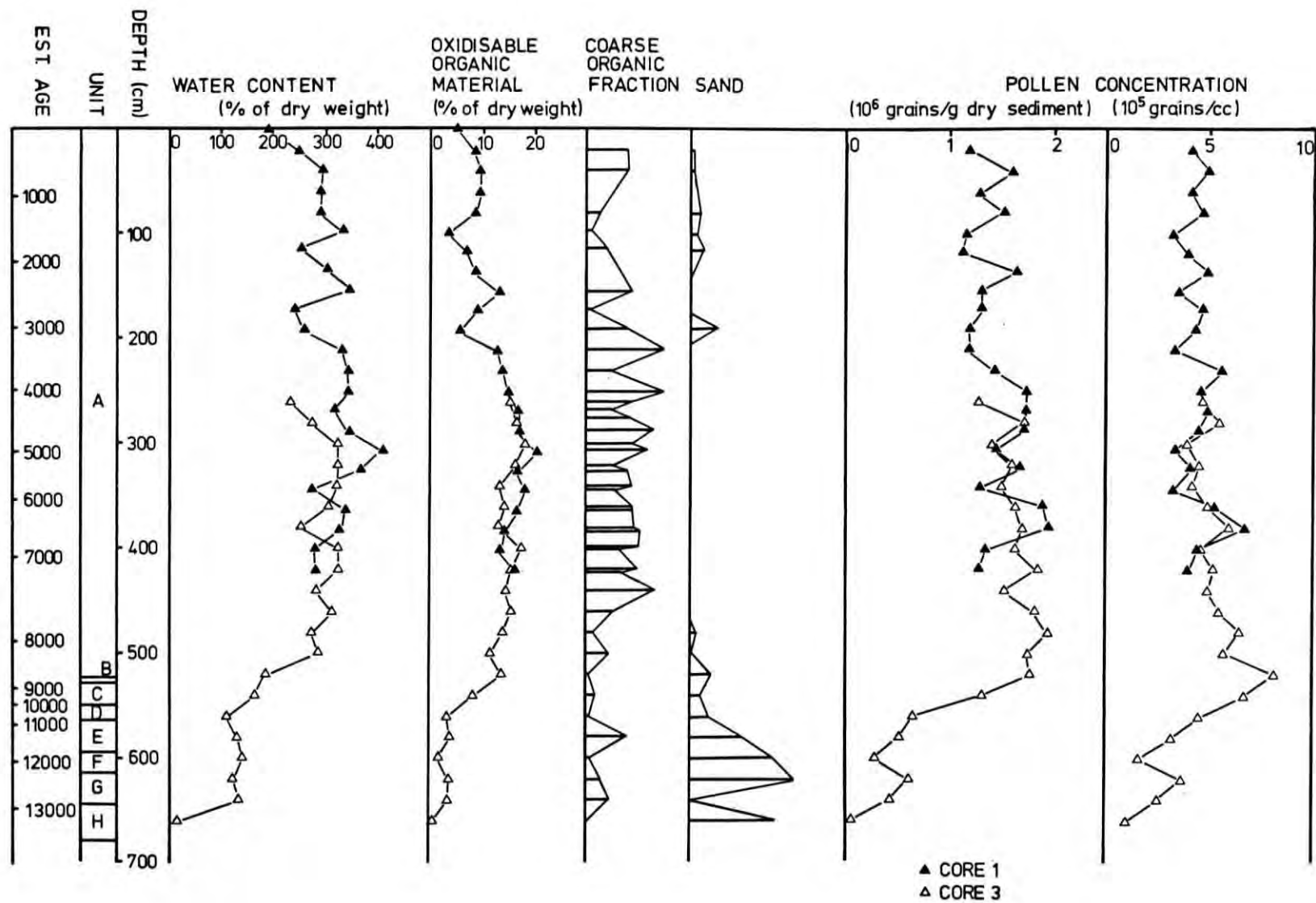


FIG. 3.5 DEPTH PROFILES OF SELECTED SEDIMENT FRACTIONS, BLUE LAKE CORES 1&3

apparently twigs. Absence of stratification is relieved only by scattered laminae of detritus herbosus, mainly between 390 and 450 cm, but also at 154 and 209 cm, and by mud laminae at 136 and 452 cm. There are also rare subangular granitic pebbles. Oxidizable organic material varies from 3½ to approximately 20%, and is apparently correlated with water content, which varies from 200 to 400%. Both are relatively low at the surface, and highest at about 300 cm, and both exhibit negative departures from the general trend at about 100 cm and 180 cm depth. As might be expected, coarse organic material is also relatively low at these levels, and also near the base of the unit, while the trace of sand present is higher. Pollen content declines irregularly through the unit, from about 1.8×10^6 grains/gram or 7×10^5 grains/cc to about 1.4×10^6 grains/gram or 4.5×10^5 grains/cc. It is not certain whether fluctuations in pollen content parallel those in organic material, although all curves exhibit a low at about 100 cm depth. In a succeeding section (Pollen Deposition Rate) it will be shown that at least some fluctuations are not merely random.

The unit may also be recognized as including all of cores 4 and 6, and in cores 7 and 8, which appear to have less coarse organic material. In the latter two cores the next lower unit, B, consists of laminated silt, clay and very fine sand, and may be in part time equivalent to the lowermost part of unit A in cores 2 and 3. The lower boundary of unit B in cores 7 and 8 is marked by the transition of limus-rich mud of unit C to pebbly sand at the base of unit B, this pebbly sand probably being equivalent in time to unit B of cores 2 and 3 but thicker (10 cm) in core 2.

Unit B, 524-526 cm in core 3 but thicker (10 cm) in core 2, consists of laminated yellowish gray silt (2.5Y 2/1 to 4/1) and very fine to medium sand. It was not sampled for organic carbon or pollen analysis.

Unit C (526-550 cm) consists of brownish to yellowish black (10 YR 2/2 to 2-5Y 5/2) mud with limus, similar in appearance to the lower part of unit A. There is little coarse organic material and some sand in pollen sample residues, again like the lower part of unit A but oxidizable organic material is lower, at about 8%, as is water content, at 170%. Pollen content is

similar, at about 1.3×10^6 grains/gram or 7×10^5 grains/cc. In cores 7 and 8 equivalent sediments may be recognized, slightly sandier.

Unit D (550-565 cm) consists of yellowish gray (2.5Y 5/1) laminated gray mud, with lower oxidizable organic material (3%), water (110%), coarse organic material and pollen content (0.65×10^6 grains/gram or 4.5×10^5 grains/cc) than the overlying unit. Similar, slightly coarser sediments, occur in cores 7 and 8.

Unit E (565-595 cm) consists of dark yellowish gray (2.5Y 4/1) laminated mud richer in limus than the overlying unit: oxidizable organic material is slightly higher (about 4%), as is water content (130%) and coarse organic material. Sand content is, however higher, and pollen content lower (0.5×10^6 grains/gram or 3×10^5 grains/cc). A similar unit may be recognized in core 7, but at this level correlation is uncertain.

Unit F (595-615 cm) consists of yellowish gray (2.5Y 5/1) laminated silt and clay with some coarse sand laminae. Oxidizable organic material (1.5%), coarse organic material and pollen content (0.3×10^6 grains/gram or 1.5×10^5 grains/cc) are lower than the overlying unit while water content (140%) is similar, and sand more abundant.

Unit G (615-642 cm) consists of obscurely laminated dark brown slightly sandy mud with limus, richer in oxidizable organic material (3-4%), coarse organic material, and pollen ($0.4-0.6 \times 10^6$ grains/gram or $2.5-3.5 \times 10^5$ grains/cc) than the overlying unit. Water content is similar (120-140%) and sand content variable.

Unit H, the lowest sediments cored (642-674) consists of yellowish gray (2.5Y 5/1) slightly pebbly laminated silt and clay. The pebbles, to 1 cm diameter, comprise subangular granitic fragments.

Core 5 consists of 40 cm of greenish gray mud. From the location of the core site and the behaviour of the corer it is likely that the sedimentary sequence is here but 50 cm thick, and that the substrate is granite, although a talus or moraine substrate is possible. No other core reached the bottom of the sedimentary sequence.

Radiocarbon dates

In order to establish sedimentation rates for calculation of corresponding rates of pollen deposition, a careful assessment of radiocarbon dates is necessary. Space does not allow a detailed exposition of the radiocarbon dating method here: a recent review has been given by Suess (1973).

Radiocarbon ages are calculated from the decay equation:

$$A_t = A_0 e^{-\lambda t}$$

where A_t is C^{14} radioactivity of the sample
 A_0 is the original activity of the sample
 λ is the half-life of C^{14} decay
 t is decay time, i.e. age
(e is the mathematical quantity)

A_t , A_0 and λ are all subject to uncertainties.

The precision of the measured modern activity, A_t , depends on the observed number of decay events and the precision of determination of the modern reference standard and of the background (non-sample) activity (Polach, 1969). Its accuracy, with respect to the activity of in-situ original sample material, depends on systematic errors in measurement, which are probably low, and on contamination of the sample during extraction and preparation. Blue Lake core samples submitted for analysis at the ANU Radiocarbon Dating Laboratory were c. 20 cm lengths of core from which the outer 1-2 mm had been scraped to remove material smeared along the core during corer operation. These were packed as advised by Polach and Golson (1966).

The original activity of the sample, A_0 , is unknown, and must be estimated by assuming an activity for the appropriate carbon reservoir, for terrestrial material the atmosphere, and applying corrections for the nature of the sample involved. In the case of plant material, deviation of sample activity from atmospheric reservoir activity at the time of sample formation is due to isotopic fractionation of carbon during the process of carbon fixation by plants. With plants deriving their carbon from atmospheric carbon dioxide dissolved in lake water, fractionation of carbon isotopes during solution must be taken into account, as must also the possible presence of carbon (as carbonate or bicarbonate ions) derived from old

carbonate sediments in the lake catchment. In the Blue Lake catchment there are no carbonate rocks, and analyses (Williams, Walker and Brand, 1970) show the lake water to be exceptionally poor in dissolved salts, less than 3 ppm, presumably because of high water renewal rate in the lake. Thus 'carbonate error' does not appear to be an important factor with the Blue Lake samples.

Apart from terrestrial and lacustrine plant material the organic fraction of the sediments dated included animal remains, which can be expected to have a similar initial activity to that of the plant detritus upon which they fed, and humic colloids. In part these are derived from in-situ decay of plant material, possibly involving slight fractionation of carbon, and in part from soils in the catchment area. As Rafter and Stout (1969) have shown, there is a rapid turnover in soil organic material, so that even complete erosion of a soil and deposition of its total organic carbon content as lake sediment would not yield a sediment with an apparent age, at time of formation, of more than about 50 years. Erosion of peats might, however, introduce a significant proportion of 'old' organic material, and this is a factor which would be likely to vary considerably with time.

In practice, the radiocarbon dates have been corrected by assuming a deviation of sample activity from contemporaneous atmospheric activity, derived from measurements on modern sediments, of -48.0 ± 4.0 per mil (Craig, 1953; Polach, 1969), and an atmospheric activity equivalent to that of a wood standard at the time of its formation in 1890 AD. A half-life of 5568 years was used to calculate the reported ages, which are listed in Table 3.1, together with three results from a core obtained by Costin (1972). The error stated is based only upon uncertainties of physical measurements, and does not include uncertainty in the half-life determination. It is quoted as one standard deviation. Ages are with respect to the year 1950 AD (B.P. = before this year). Reliability of the ages will be discussed in the next section.

Before the dates can be used for estimation of sedimentation rates, two further corrections must be made. The first of these is relatively simple, and consists of multiplying the reported ages by 1.031 to bring them into line

with the more recently determined half-life of 5730 years (Mann, Marlow and Hughes, 1961).

The second correction is due to inaccuracy of the assumption that the radiocarbon content of the atmospheric carbon reservoir was the same in the past as it was in 1890. For various reasons (Olsson, 1970) it has fluctuated, as has been shown by dating samples of independently estimated age, such as archaeological material, tree rings, and varved sediments. Dendrochronology appears to have provided the most accurately dated comparison samples but so far these exist for only the last 7350 years (Ralph, Michael and Han, 1973).

Figure 3.6 represents a compilation of estimates of the deviation of past atmospheric radiocarbon activity from the atmospheric activity represented by the 1890 wood standard. The following data are included:

- 1) Tauber's (1970) comparison between varve dates and radiocarbon dates for late-glacial and post-glacial events in Scandinavia. The points marked (1), corresponding to the transition from the Ancylus Lake to the Littorina Sea in the Baltic area, are based on alternative estimates of the time of influx of salt-water diatoms into the sequence.
- 2) Stuiver's (1970) comparison of varve and radiocarbon dates over the last 10,000 years for a core from the Lake of the Clouds, Minnesota.
- 3) Vogel's (1970) comparison of varve and radiocarbon dates from sediments at Niederwil and the Faulenseemoos in Switzerland. The limit of apparently reliable varve-dating is stated to be 9500 years B.P.
- 4) Che Yang and Fairhall's (1972) comparison of varve and radiocarbon dates from marine sediments of Saanich Inlet, British Columbia. These sediments contain terrestrial plant remains back to 8700 years B.P., enabling atmospheric activity to be estimated over this interval. In addition, whole-sediment dates, reflecting, according to the authors, the activity of upwelled deep-ocean water, provide a record back to c. 11,000 years B.P. Variations in this activity should show a phase lag relative to variations in that of the atmosphere, and a lag of 1000 years is in fact demonstrated.

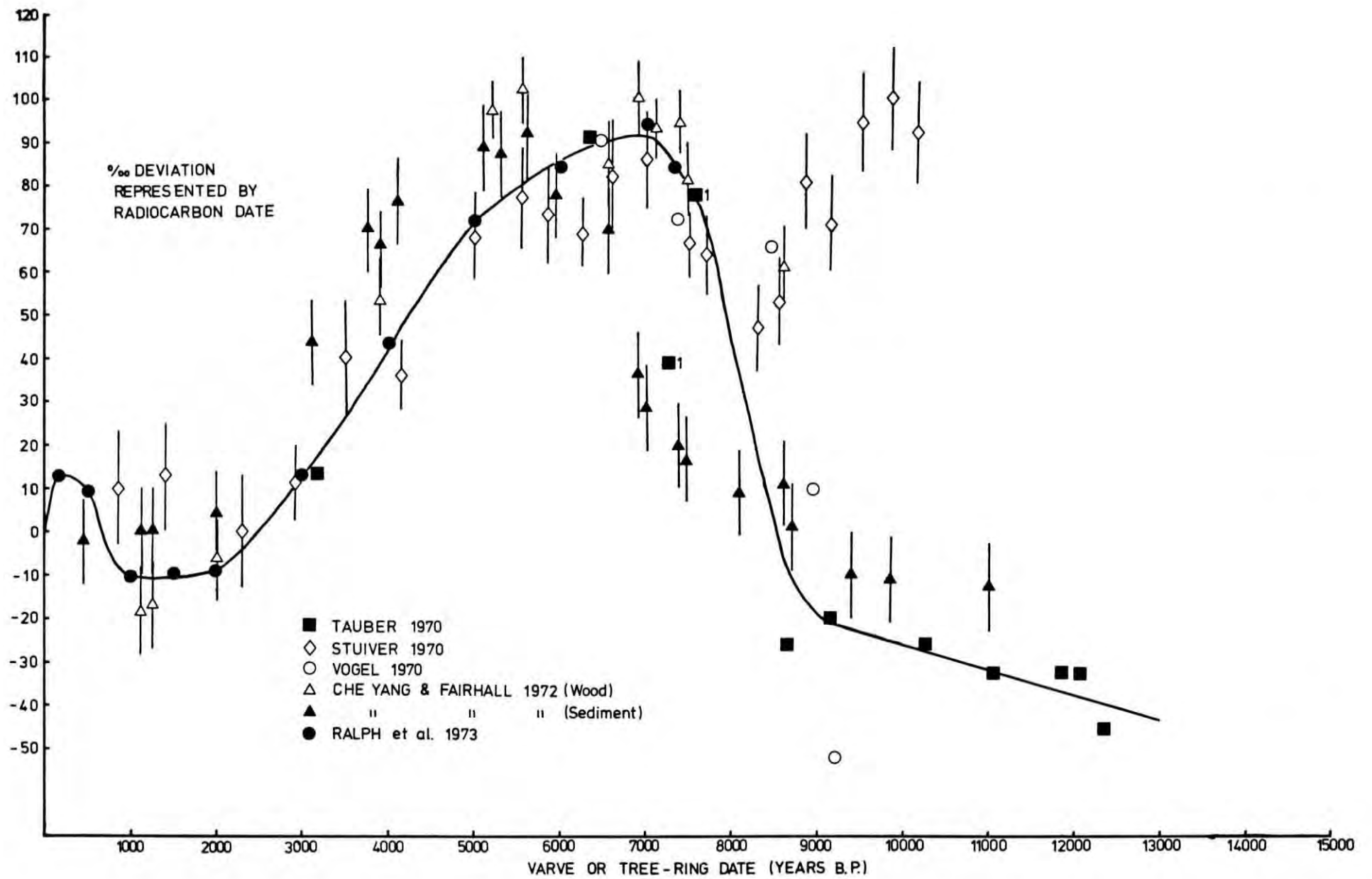


FIG. 3.6 COMPILATION OF RADIOCARBON SECULAR DEVIATION RESULTS

Table 3.1 Summary of Radiocarbon Dates from Blue
Lake Cores

Laboratory Code*	Core	Sequence Depth (cm)	Reported Age \pm error ($t_{1/2}$ = 5568 yrs)	Age corrected for $t_{1/2}$ = 5730 yrs	Age corrected for secular variations
ANU-892	6	20-40?	1880 \pm 70	1935	1950
ANU-1093	1	79-97	920 \pm 60	947	890
ANU-886	2	111-131	2710 \pm 80	2789	2890
ANU-1094	1	144-165	2330 \pm 70	2398	2420
ANU-887	2	211-231	3160 \pm 80	3252	3420
ANU-888	2	311-331	4630 \pm 90	4764	5290
ANU-1095	3	361-378	6580 \pm 90	6771	7400
ANU-889	2	406-426	4070 \pm 80	4188	4510
ANU-1096	3	461-480	7210 \pm 90	7419	7800
ANU-890	2	494-514	7820 \pm 110	8047	8200
ANU-891	2	530-541	8580 \pm 190	8829	8750
ANU-1097	3	531-550	9830 \pm 140	10115	9820
ANU-1098	3	621-640	12620 \pm 240	12986	12650
NZ-586		0-30	827 \pm 100	851	800
NZ-587		145-175	1670 \pm 105	1718	1640
NZ-588		305-338	5910 \pm 140	6081	6720

* Laboratories: ANU = Australian National University.
 NZ = Department of Scientific and
 Industrial Research, New Zealand.

- 5) A recent compilation of dendrochronology-radiocarbon data results (Ralph, Michael and Han, 1973). Only selected points from the mean curve have been plotted; the period covered is the last 7350 years.

Taking into account the phase lag of 1000 years in the Saanich Inlet sediment dates, and choosing the older varve date for flooding of the Ancylus Lake, there is general agreement back to about 8000 years B.P. Before this date there is a discrepancy between Stuiver's Lake of the Clouds results and the results of Tauber, Vogel, and Che Yang and Fairhall. Although at least one author (Maher, 1972) has based radiocarbon date corrections on the Lake of the Clouds results, their acceptance would imply an error of about 1000 years in the Swedish varve chronology. This seems unacceptable, hence Lake of the Clouds results for the period before 8500 years B.P. have been disregarded in the drawing of a mean correction curve. This correction curve, drawn in figure 3.6 as per mil deviation from a standard, is shown in figure 3.7 as a radiocarbon date-corrected date graph.

Calibration curves based on tree-ring samples have indicated the occurrence of large short-term variations in atmospheric radiocarbon content. Since the periods of these fluctuations are generally shorter than the period represented by a core sample, which gives an average over at least 200 years, they have not been considered to be significant in the present study.

Corrected Blue Lake radiocarbon sample ages are given in Table 3.1. It can be seen that the greatest corrections are to dates of the order of 6000 years B.P.: for example with ANU-1095, the correction is + 629 years, or 9.3% of the original estimated age.

One further point requires mention at this stage. This is that there appears to be a slight latitudinal variation in atmospheric radiocarbon content. Lerman *et al.* (1970) suggest a constant average deficiency of radiocarbon in the southern hemisphere of 4.5 ± 1 per mil, whereas Jansen (1970) has suggested that the difference increases with age. Both studies were based on wood samples either explicitly or

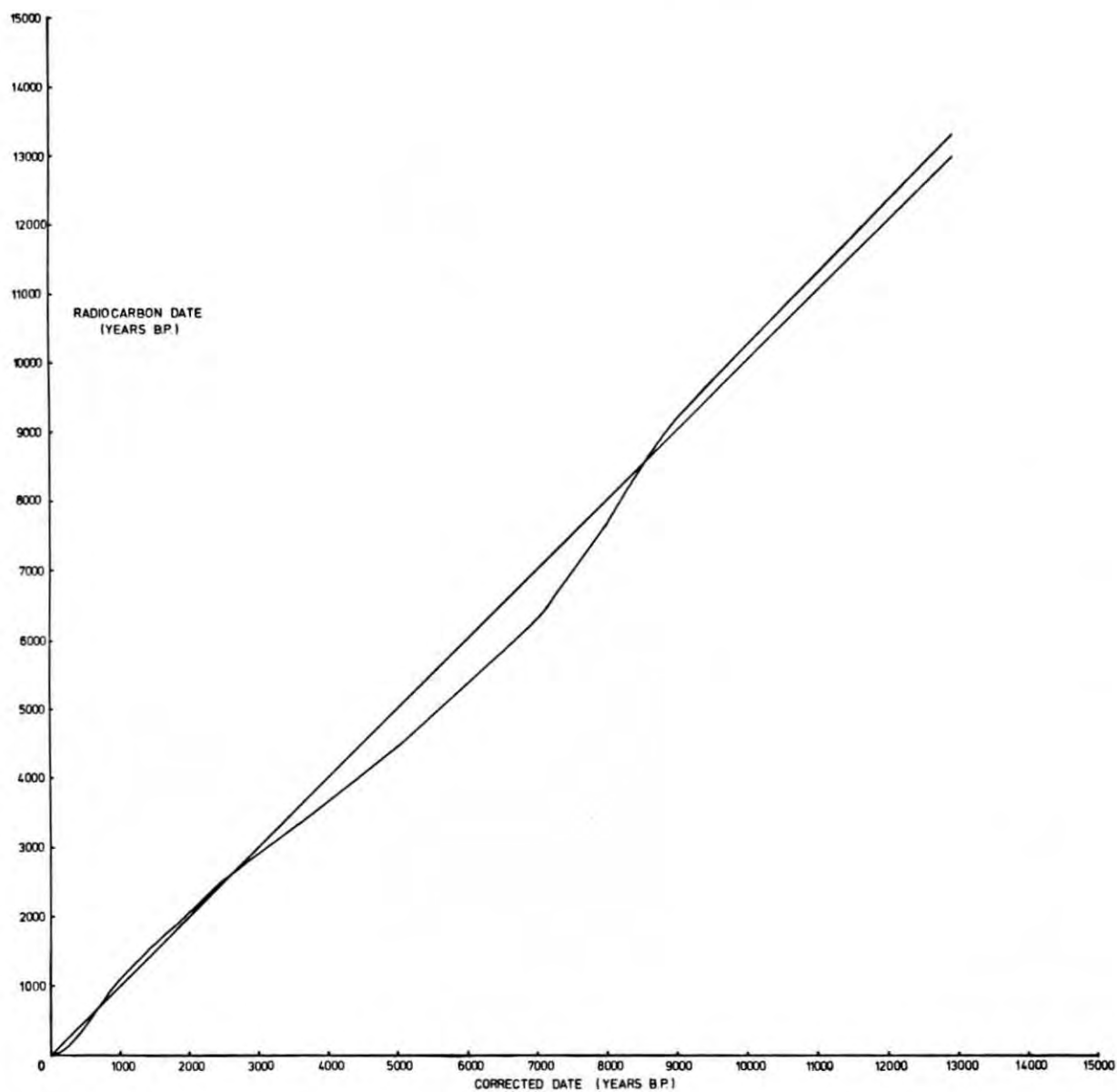


FIG. 3.7 CORRECTION CURVE FOR RADIOCARBON DATES BASED ON SECULAR VARIATION RESULTS (FIG. 3.6)

apparently dated by a simple count of annual tree rings. Until these studies are supported by detailed dendrochronologic research it may be wise to treat the results with caution. A slight deficiency in southern hemisphere atmospheric radiocarbon content is, however, suggested by reservoir theory; 4.5 per mil deficit implies that southern hemisphere ages should be corrected by subtracting approximately 35 years from the ages based on northern hemisphere standards. The above-mentioned studies have indicated that variations in atmospheric radiocarbon content with time follow similar trends in both hemispheres over the past few hundred years.

Sedimentation Rate in Blue Lake

The following discussion refers only to the radiocarbon-dated and pollen-analysed cores.

Radiocarbon dates corrected for the 5730-year half-life of C^{14} and for secular variations in atmospheric radiocarbon content are plotted versus sample depth in figure 3.8. Costin's core dates are also plotted for comparison, although these must not be relied upon too heavily, as, although the core is believed to have been taken from a similar location, detailed correlation of the sediments has not been possible. All his samples, however, are derived from sediment unit A described previously. Because of uncertainties in the correction method, no error bars have been plotted.

It is evident from the figure that the date of 1950 years B.P. (ANU-892) from the top of core 6 is too old for the apparent sample depth. It is likely that this is due to the corer having anchored in the sediment more deeply than expected.

Other anomalies concern dates from core 2: ANU-886 at 2890 years B.P. and ANU-889 at 4510 years B.P. The former date appears too old by comparison with the two dates from core 1 (see also figure 3.3. and Table 3.1). The latter date involves a date inversion within core 2, and appears too young by comparison with the top two dates of core 3. The lowermost date of core 2, 8750 years B.P., is also at first sight in conflict with the 9820 years B.P. date from core 3 (ANU-1097). The core 2 date was based on a small sample (reflected in its higher reported error) and was thus more likely to be seriously affected by contamination. In addition, the core 3 date sample included half its material from greater depth, so would

be expected to be a little older. Core 1 and core 3 date samples were more ruthlessly pared to remove material smeared along the core, the suspected cause of core 2 date anomalies. Dates from these cores were therefore given more weight in drawing a depth-age curve.

Despite the likelihood of inaccuracies in the dates used, the best estimate of depth-age relationships is obtained by drawing a curve to pass through the observed points. Least-squares lines of best fit, and the like, could be drawn (Ogden, 1967) but there is no justification for assuming a simple relationship of the kind implied by these operations. Changes in the nature of the sediment, and in the vegetation cover of the lake catchment (implied by pollen spectral changes) both strongly suggest that changes in sedimentation rate have occurred, and that these changes follow no simple pattern. A line was therefore drawn by eye so as to pass through the points deemed most reliable, with constant sign of slope, avoiding extremes of slope, and with as few points of inflection as possible.

For the period between 4500 and 8000 years B.P. three curves have been drawn, reflecting differing degrees of confidence in the date ANU-1095 (7400 years B.P.). This date is supported by NZ-588 (6720 years B.P.). Curves B and C show a continuation of the trend to increasing sedimentation rate implied by the three dates ANU-891, ANU-890 and ANU-1096, but also require a reduced sedimentation rate between 7000 and 4500 years B.P., if weight is still given to ANU-888. Sedimentation rate graphs drawn from the depth-age curves in figure 3.8 are shown in figure 3.9.

Sedimentation rate declined from a time before 13000 years B.P. (basal core sediments) until about 9000 years B.P. (unit C), in line with a decreasing proportion of coarse material in the sediment. After 9000 years B.P., possibly at the beginning of unit B, sedimentation rate rose abruptly, reaching a peak between 8000 and 7000 years B.P. The magnitude of this peak depends on interpretation of the radiocarbon dates, but its occurrence is consistent with the higher proportion of detritus herbosus in the sediment, present also as discrete laminae, between 400 and 500 cm depth. Sedimentation rate reached a minimum value, for unit A, at about 6000 years B.P., after which it apparently rose to recent levels.

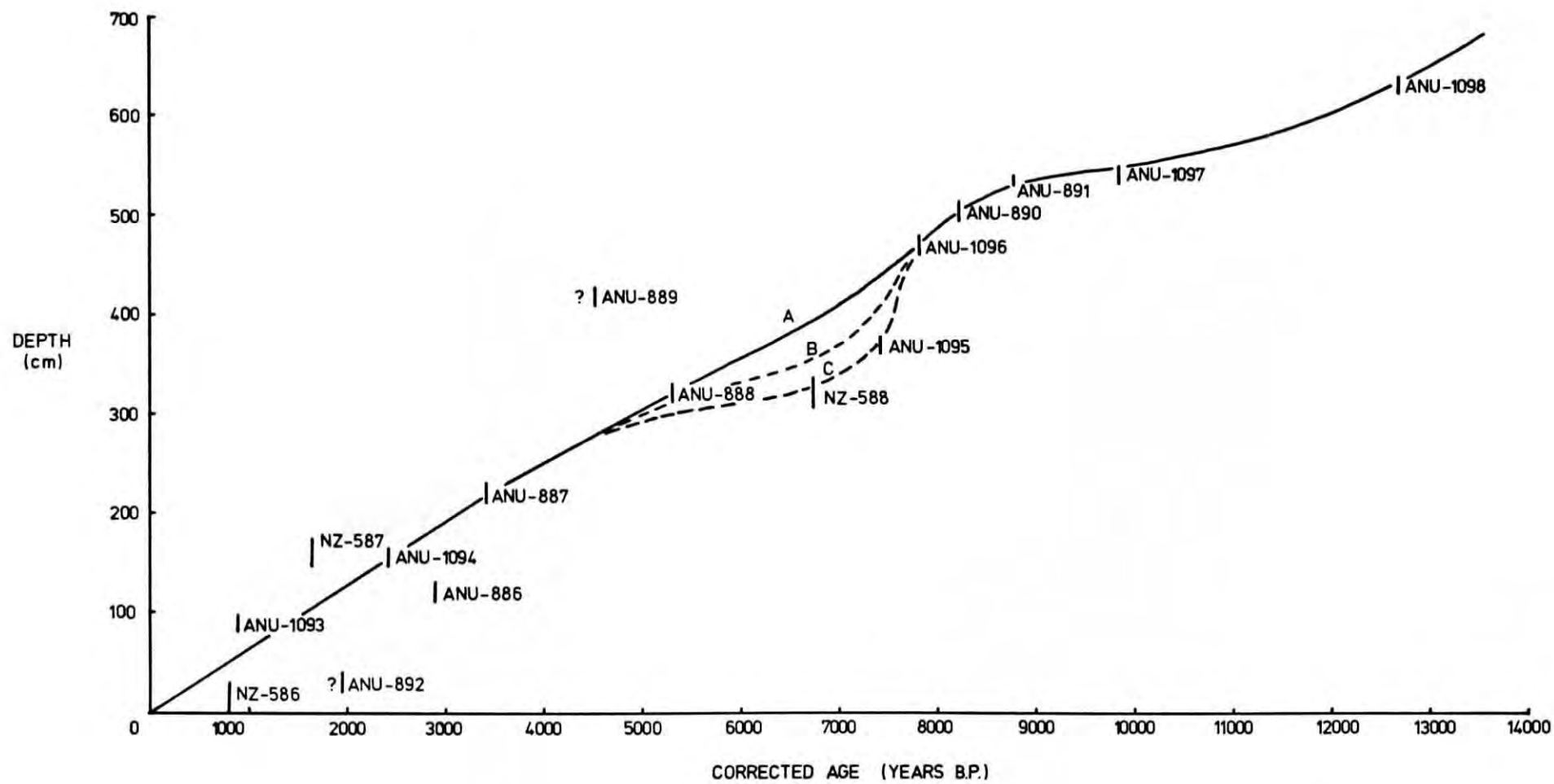


FIG. 3.8 CORRECTED AGE VERSUS DEPTH

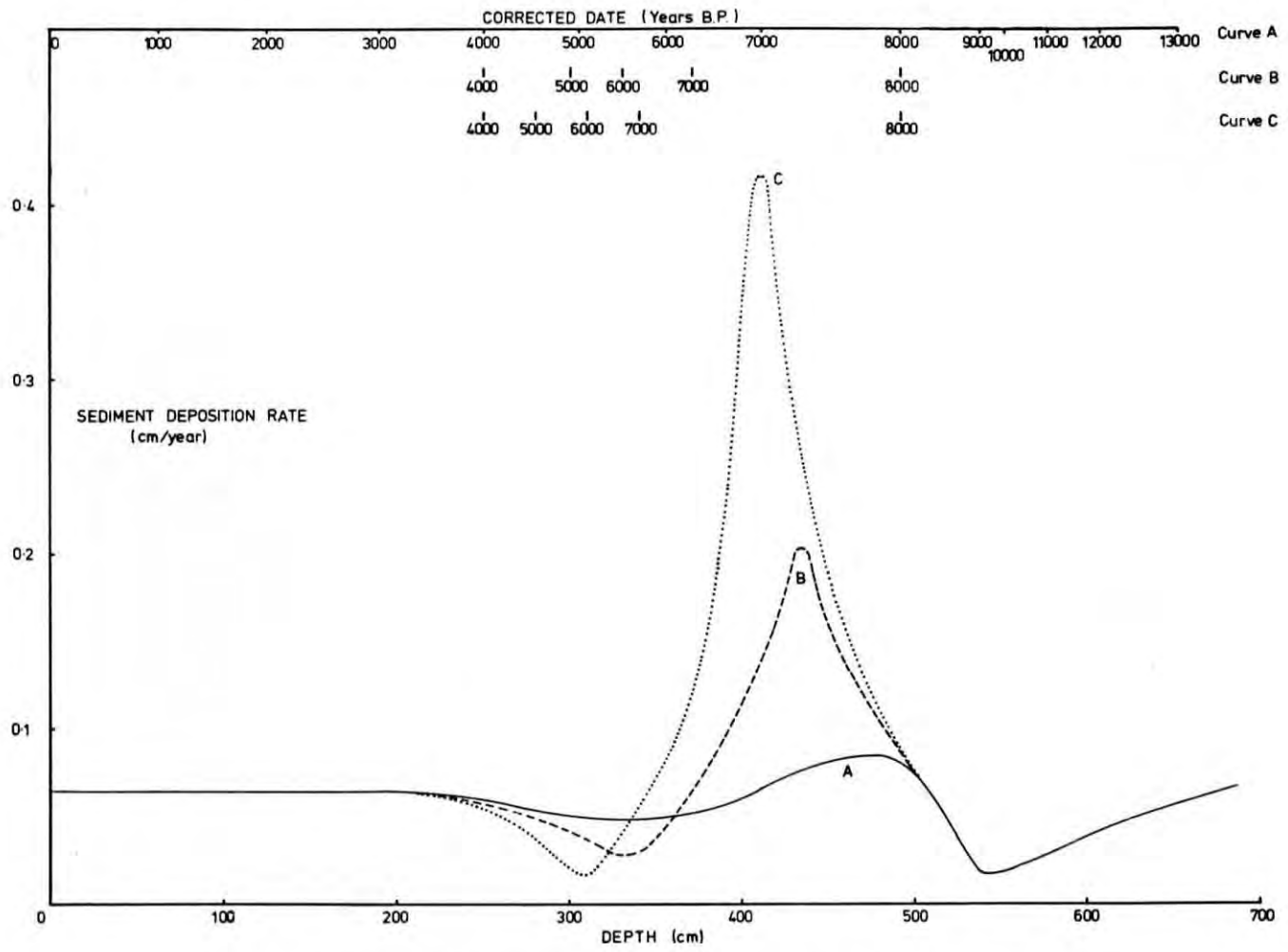


FIG. 3.9 SEDIMENTATION RATE FOR BLUE LAKE CORES 1 & 3

The conservative sedimentation rate curve A was chosen for calculation of pollen deposition rates.

Pollen Deposition Rate

Pollen concentration as a function of depth is plotted in figure 3.5 in two ways, as grains/gram of dry sediment and as grains/cc of fresh sediment. For the section between 250 and 420 cm estimates are available from both cores 1 and 3. With both concentration plots mean concentration values from the two cores compare well, but the correlation between values for similar levels is much better in the case of grains per unit volume.

Core sample depths may be assumed equal for the purpose of an analysis of variance of the latter pollen concentration estimates. The following table (Moroney, 1970) results:

Source of variance	Sum of squares	Degrees of freedom	Variance estimate
Between cores	46.7×10^8	1	46.7×10^8
Between sample depths	1297.1×10^8	8	162.1×10^8
Residual	71.8×10^8	8	9.0×10^8
Total	1415.6×10^8	17	

Supposing that all samples yield equal results, then the three independent estimates of variance are all estimates of the variance of a common parent population where variability exists for reasons other than inter-core or depth effects. They should therefore appear as compatible estimates under Snedecor's Variance Ratio Test:

- 1) In the case of variance between cores,

$$\text{Snedecor's } F = \frac{\text{between cores variance estimate}}{\text{residual variance estimate}} = 5.18$$

This value of F just fails to exceed the 5% probability level of 5.32, hence the null hypothesis (that the between cores variance component is not significantly different from residual variation) cannot be rejected.

- 2) In the case of variance between sample depths,

$$F = \frac{\text{between depths variance estimate}}{\text{residual variance estimate}} = 18.0$$

This value of F, for the appropriate number of degrees of freedom, exceeds the 1% probability level of 6.03, and the null hypothesis (that the variance between depths is not significantly different from residual variation) is rejected.

Thus (1) results from the two cores are compatible and (2) there is a significant variation of concentration with depth. Individual sample variance may be obtained by dividing the sum of the residual and inter-core variances by the appropriate number of degrees of freedom (9). The result is 13.2×10^8 . The mean individual standard deviation is the square root of this variance, and is equal to 3.63×10^4 , or 7.8% of the average concentration over the interval. This result compares well with the coefficient of variation estimated in Chapter 2 as $100\sqrt{.0009 + \frac{1}{N}}$, which is 7.7% for a count of 200 grains.

A similar analysis of variance of the per unit weight pollen concentration results failed to discover significant variation with depth, possibly because of the greater accumulated error associated with determination of sample dry weight.

The effect of applying the sedimentation rates of figure 3.9 to calculation of pollen deposition rate can be seen in figure 3.10. In general, peaks in the per unit volume concentration curve are emphasized in the deposition rate curve. This implies that increased whole sediment sedimentation rate is correlated with increased pollen deposition.

Pollen deposition rate was lower before 9000 years B.P. than in the period since, although a minor peak occurred between 13000 and 12000 years B.P. (unit G). The rate increased abruptly at the base of unit A, reaching a peak at about 8000 years B.P., then declined to a minimum between 6000 and 5000 years B.P., before rising slightly. Since 4500 years B.P. pollen deposition rate appears to have oscillated about a mean value of c. 27000 grains/sq.cm/year.

Pollen Diagram Construction

Samples were taken at 20 cm intervals from cores 1 and 3 and processed and counted as described in Chapter 2. The taxonomy of pollen, spore and microfossil types is presented as a series of keys in Appendix A, together with illustrations. Table D.1 of Appendix D serves as a guide to the computer print-out tables of individual taxa, D.2 and D.3, as well as providing brief ecological information. These tables each contain, as a preamble, a table of sample depth, total pollen count, sample size, and total pollen plus spore concentration and deposition rate with standard error calculated according to table 2.3.

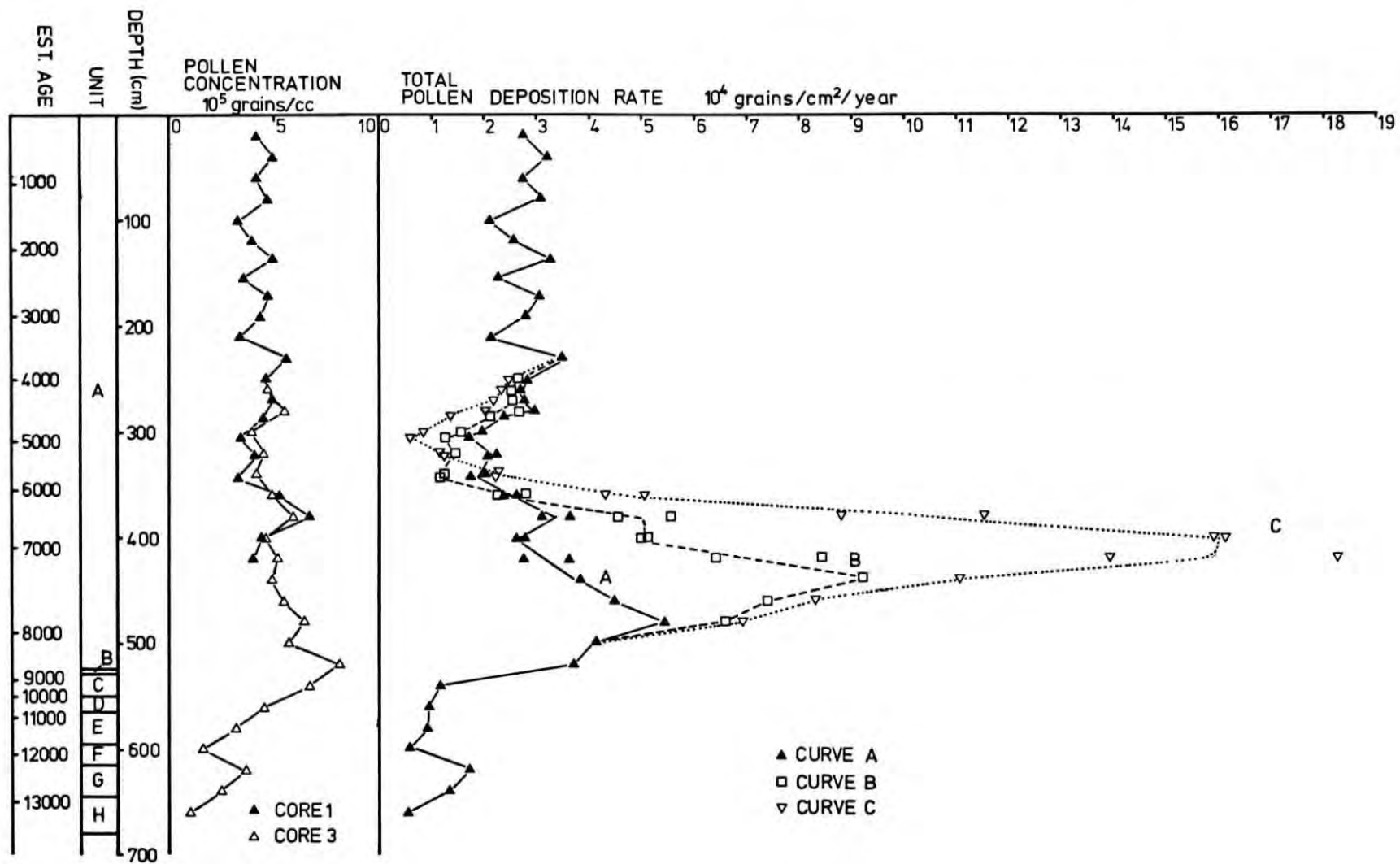


FIG. 3.10 DEPTH PROFILES OF POLLEN CONCENTRATION AND DEPOSITION RATE, BLUE LAKE CORES 1 & 3

Two diagrams are presented. The first, figure 3.11, is a conventional pollen diagram in which counts of individual taxa comprising the pollen spectrum of each sample are plotted as percentages of the 'pollen sum'. Since the occurrence of no pollen or spore type deriving from the surrounding vegetation can be regarded as irrelevant at this stage, all taxa have been included in the sum (Faegri & Iversen, 1964, p. 135). Unknown or unidentifiable grains may represent unrecognised normal components of the sum, and were also included. Microfossils apparently originating in the lake itself have been excluded, but are expressed as percentages of the pollen and spore sum, so their values may exceed 100%: these taxa include 'Sphere-W', 'Sphere-F', 'Sphere-R', 'Sphere-P', Botryococcus braunii and Baltisphaeridium. Other microfossils were distinguished, but omitted from the diagrams because they were not counted consistently. Total pollen count, concentration and deposition rate figures include all identified and unidentified pollen and spores counted except the abovementioned microfossils, to enable comparison of samples with different degrees of preservation.

The accuracy with which relative pollen frequencies are established depends on the value of the observed proportion and the number of grains counted (Faegri & Ottestad, 1948). With a high total number, statistical errors are reduced, especially for those types that occur only rarely in the sample. Faegri and Iversen (1964, p. 127) show that even moderate demands for exactness, for example that the true percentage value should be within 2/5 of the indicated value with 95% confidence, "... are fulfilled only rarely, and as soon as percentages approach low values, these demands are practically impossible to satisfy". Thus, for a pollen type with observed relative frequency of 10%, 900 grains must be counted to reach the above limits of precision. In practice, time and expense usually prevent such large counts. Kershaw (1973) found that a pollen sum of 150 grains gave reasonably consistent frequencies for the common taxa of sclerophyll forest in north Queensland. This was aimed at as a minimum value in the present investigation, and means that the variations of the pollen curves must be very pronounced for one to be certain that the observations are 'real' and do not represent sampling errors. Attention is thus concentrated on the main features of the diagram, which may be not unwise in a region previously

unexplored by pollen analysis. There remains the possibility, too, of combining ecologically similar rare taxa into groups whose frequencies can be more easily assessed.

The second diagram, figure 3.12, has been termed a pollen deposition rate (PDR) diagram to distinguish it from the first, relative pollen frequency (RPF) diagram. Total pollen deposition rate was partitioned among the taxa, according to their proportion of the pollen sum, by the program PLOTABS (Appendix B) which also calculated RPF and drew the diagrams on a CALCOMP plotter. The program POLGRP was used to manipulate the raw counts for input to PLOTABS.

Both diagrams have a similar format, taxa being arranged, reading from the bottom of each page, in the order of Appendix D. Sediment stratigraphy follows diagram 3.3, while estimated ages derive from diagram 3.8, curve A.

The uppermost sample is of the order of 300 years old, hence predates European settlement. In it no trace of European-introduced weeds appears, indicating little reworking of the sediment by lake fauna. A sample intended to provide post-European pollen frequencies was taken from mud obtained by a diver in 1970 and given to the author by the Soil Conservation Service. This also failed to show greater abundance of introduced plant pollen, although sediment trap samples contain a fair proportion. It is probable that most disturbance and introduction of weed species has occurred in the last 80 years: the mud sample may easily have been taken from below the approx. 5 cm of ooze which would represent this period.

Zonation

Zonation of pollen diagrams serves two practical purposes: the description of variation within diagrams, and correlation between them. In the case of the Blue Lake diagram zonation is difficult for several reasons:

- 1) Increases (and similarly decreases) in frequency of various taxa do not appear to be synchronous.
- 2) Few taxa present in significant proportions show much variation in RPF.
- 3) Random fluctuations due to the small numbers of pollen counted obscure general trends.
- 4) Sample spacing was too great, especially in the lower part of the diagram, to establish the significance of minor short-term fluctuations.

The latter two difficulties could be resolved by increasing the number of samples and number of pollen counted per sample, but this was not within the scope of the present investigation. To aid description, tentative zones were established with the aid of a computer classification program, POLZONE (Appendix B). This program builds up a zonation by successively joining together stratigraphically adjacent samples or groups of samples whose spectra are most similar, until a single zone containing all samples results. Dale and Walker (1970) have shown that a similar program, which did not include stratigraphic control on union of samples, led to zonation of a British pollen diagram substantially the same as the Standard British Zonation previously established. Since the computation method in effect smooths fluctuations in frequency of the various taxa, it may result in a more stable zonation (in the sense of change due to introduction of additional information) than one based on, for example, maximum difference between successive samples. Application of the program to the Blue Lake data is discussed in Appendix B.

The zones chosen are based on a consideration of RPF and PDR values of both within-sum and extra-sum taxa. Relationship of individual taxon frequencies to the zones will be discussed in the next section. Depths and ages are:

Zone BL4	0-240 cm	0-c. 3800 years B.P.
BL3	240-380 cm	c.3800-6500 years B.P.
BL2	380-525 cm	c.6500-8700 years B.P.
BL1	525-680 cm	c.8700-13500 years B.P.

Pollen record of the plant communities

The changes with time of the frequencies of the various pollen taxa are here described according to the modern plant communities in which they are most abundant. This is not to say that these communities have existed in their modern form over the period of discussion. For example, the wind-swept feldmark communities now occupy the most exposed crests of the mountains. In a cold dry period these communities could be expected to occupy a greater range of topographic situations, resulting in both floristic and structural diversification. Communities not now present in the area may also be involved. Discussion is deferred until after presentation of the Twynam Cirque diagram.

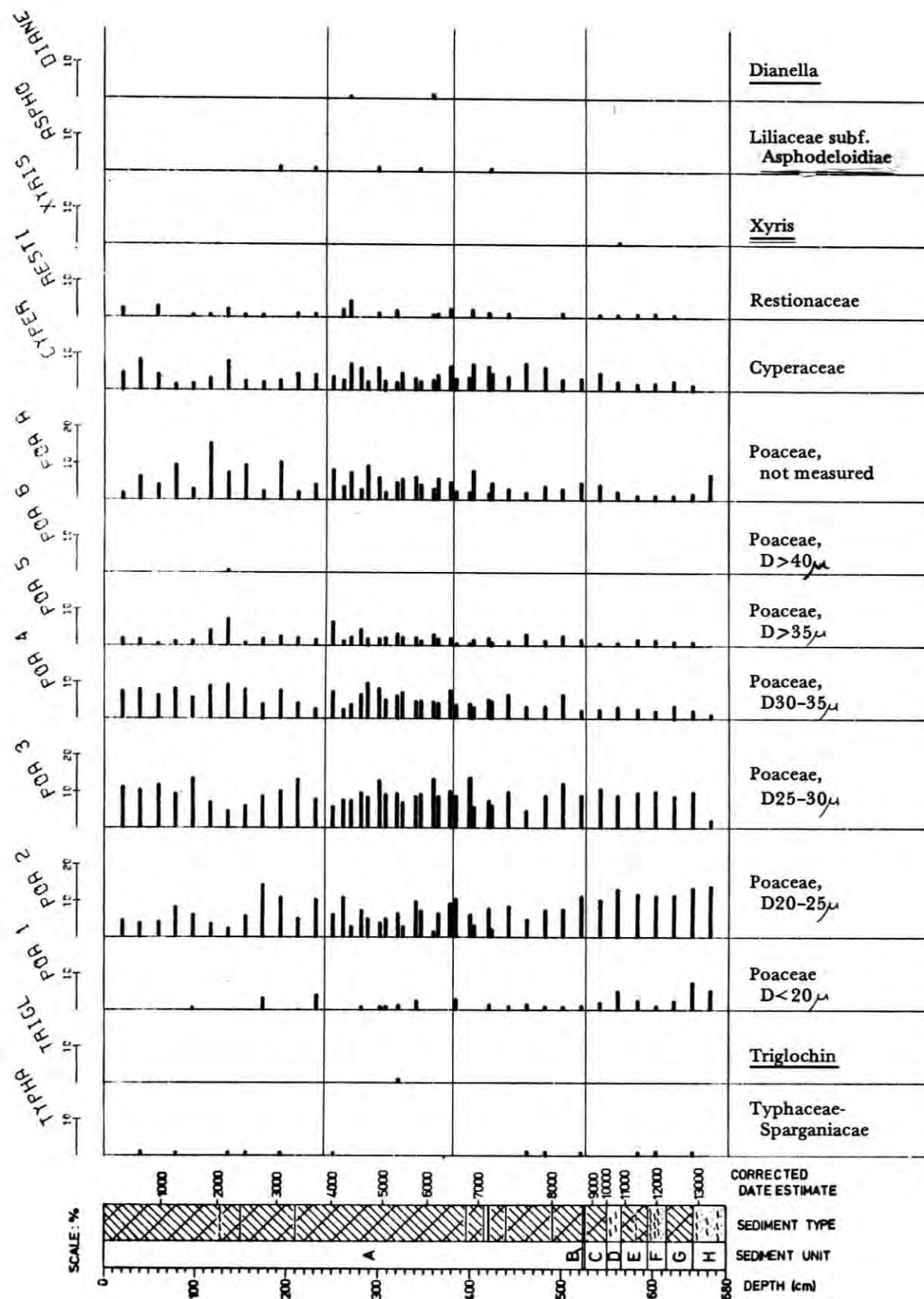


FIG. 3.11 BLUE LAKE RELATIVE POLLEN FREQUENCY DIAGRAM.

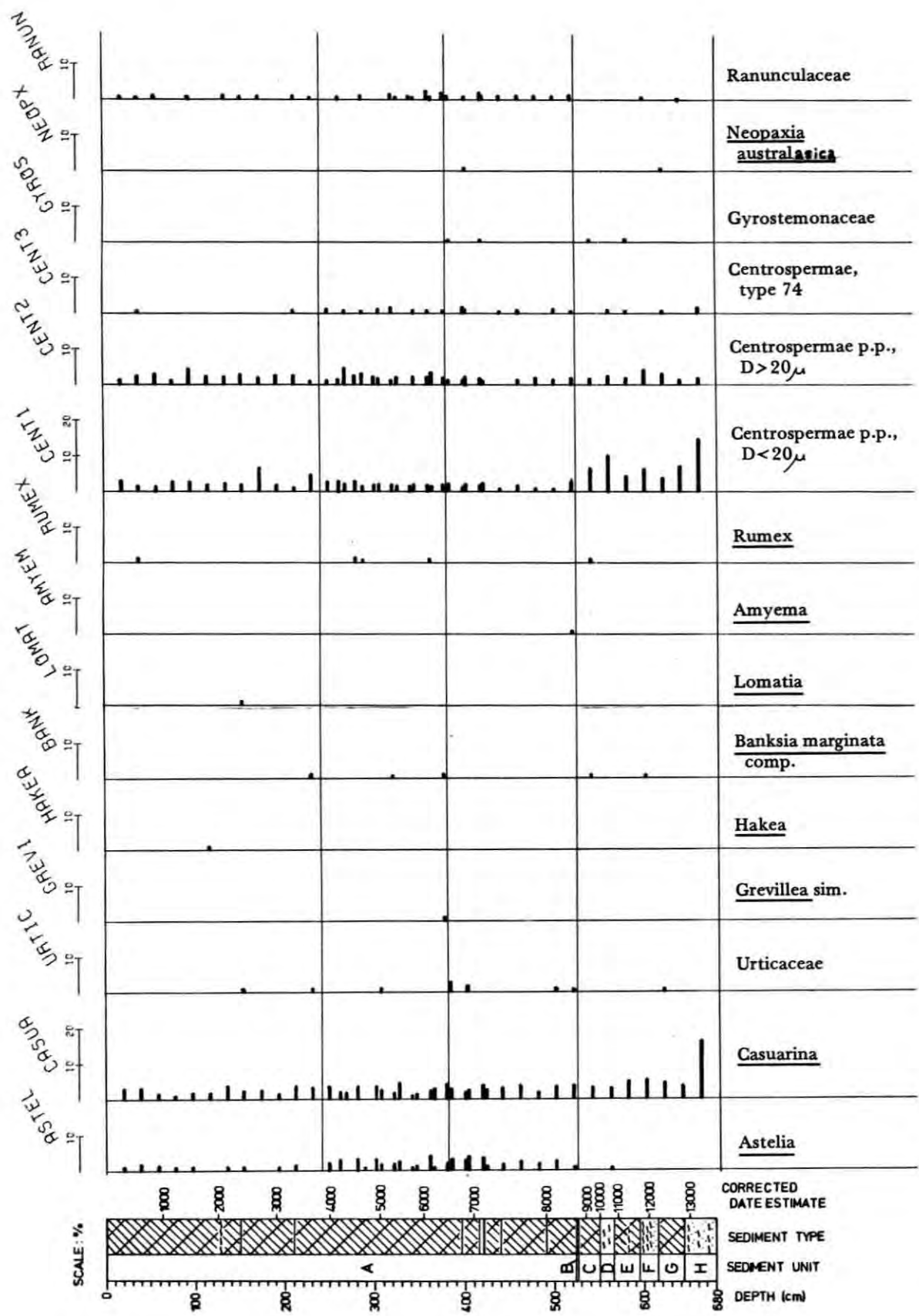


FIG. 3.11 continuation 1.

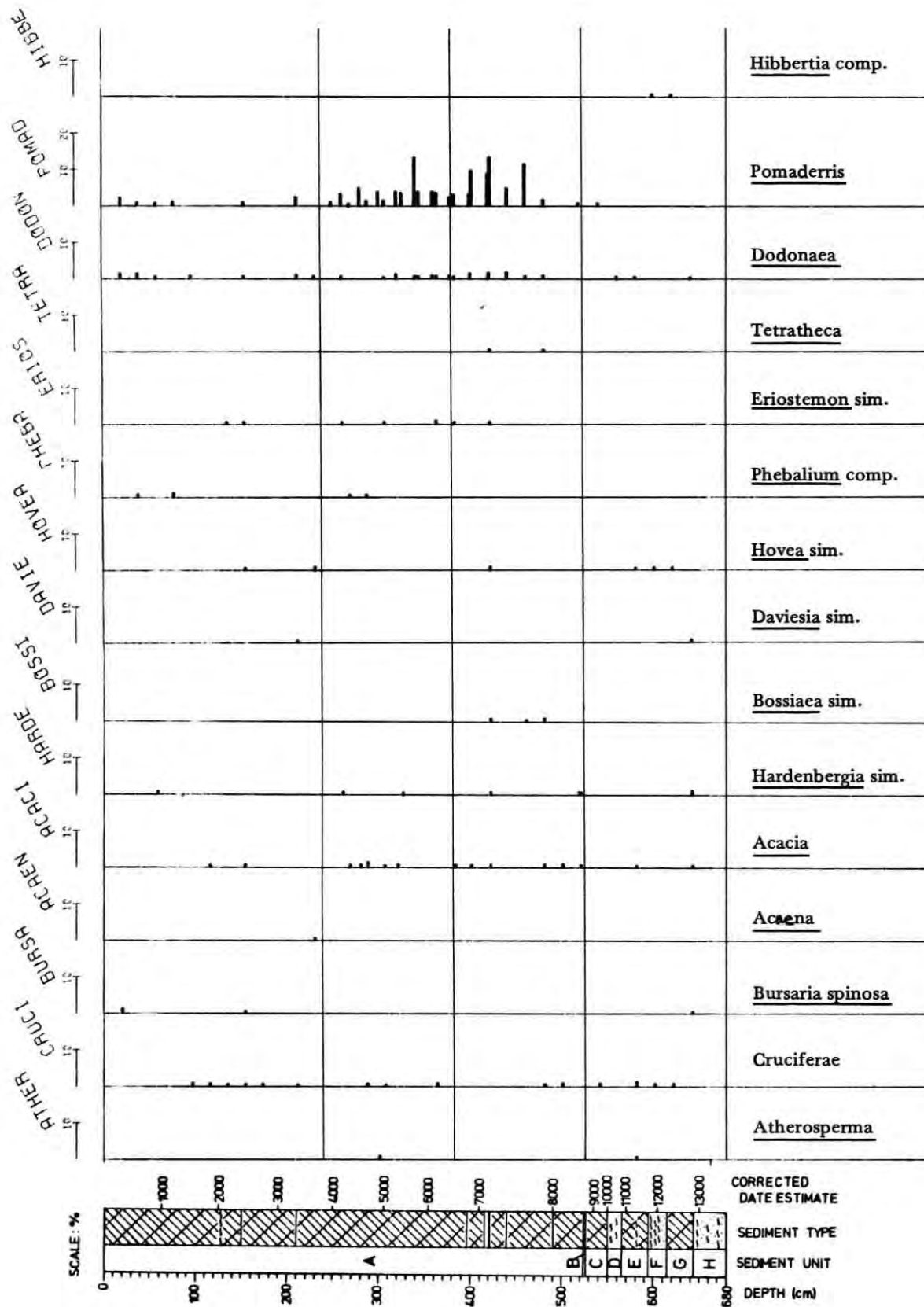


FIG. 3.11 continuation 2.

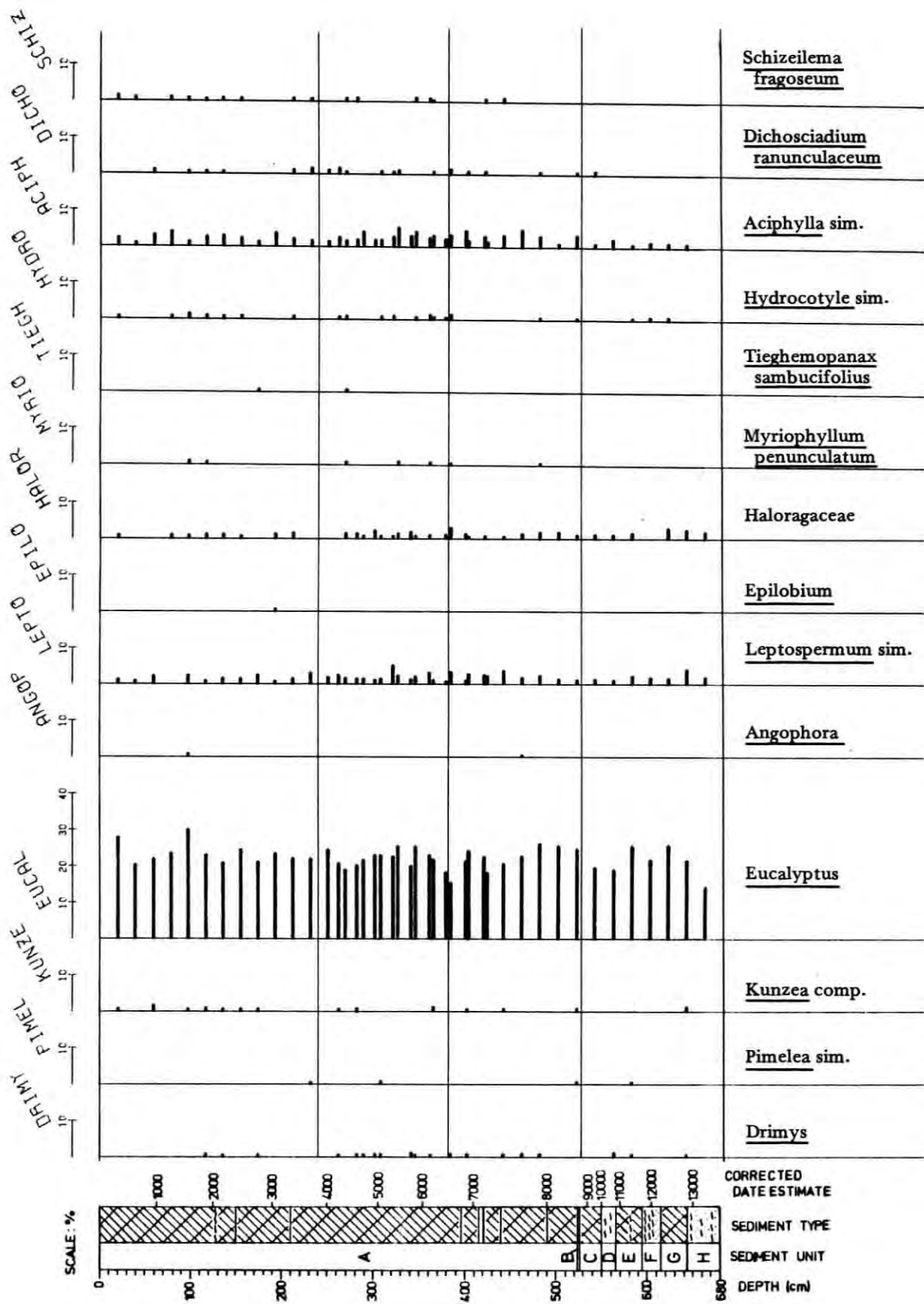


FIG. 3.11 continuation 3.

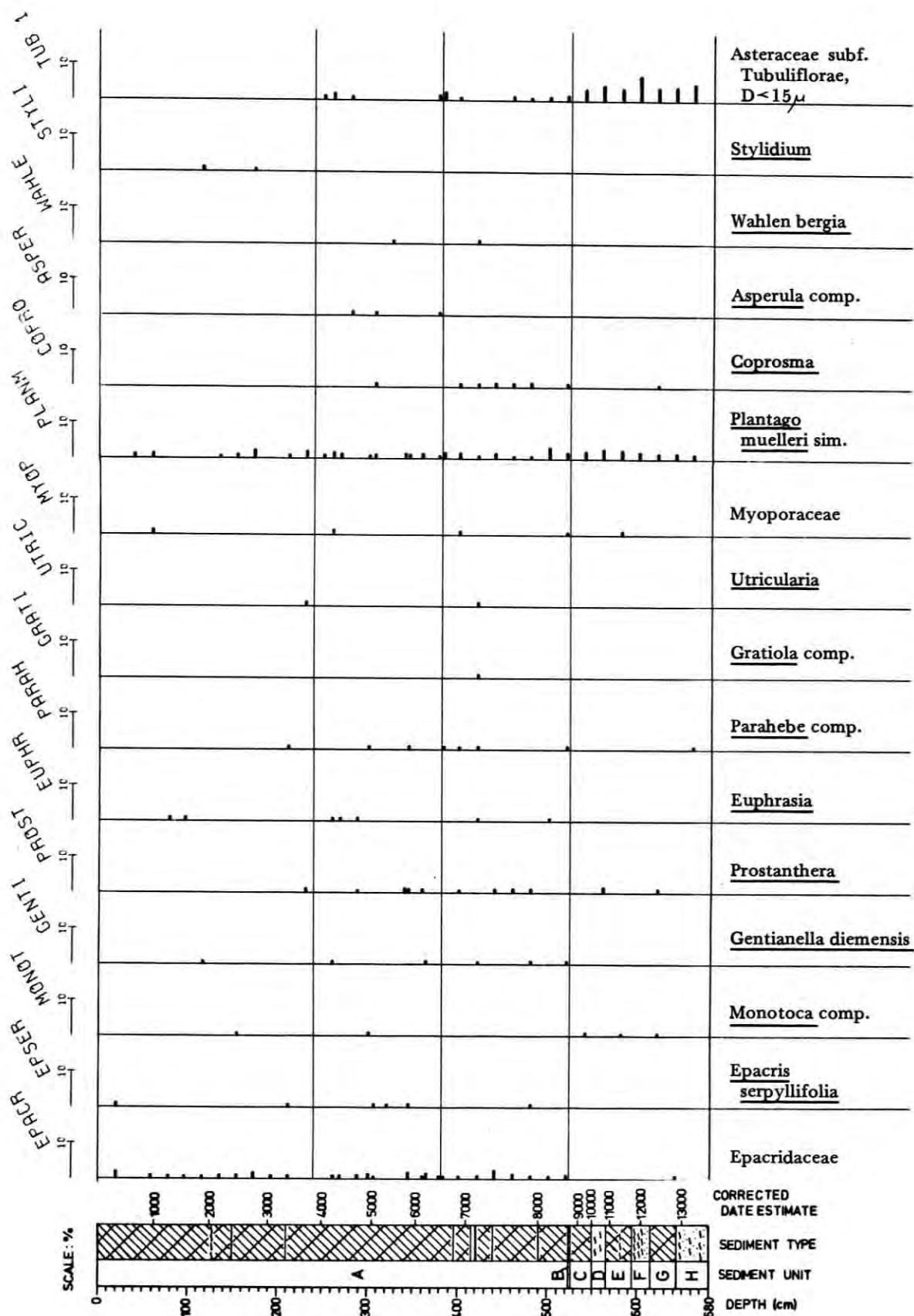


FIG. 3.11 continuation 4.

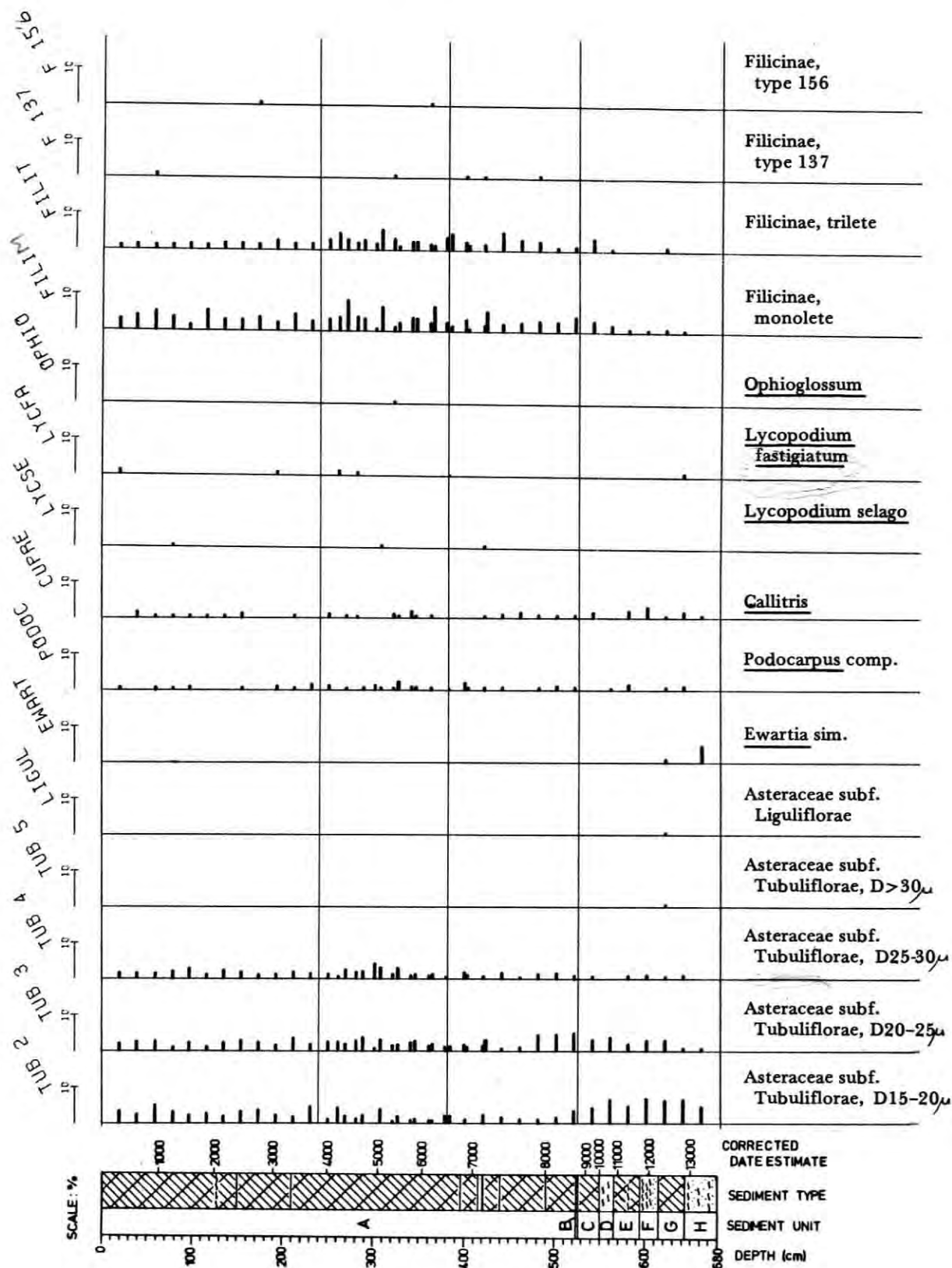


FIG. 3.11 continuation 5.

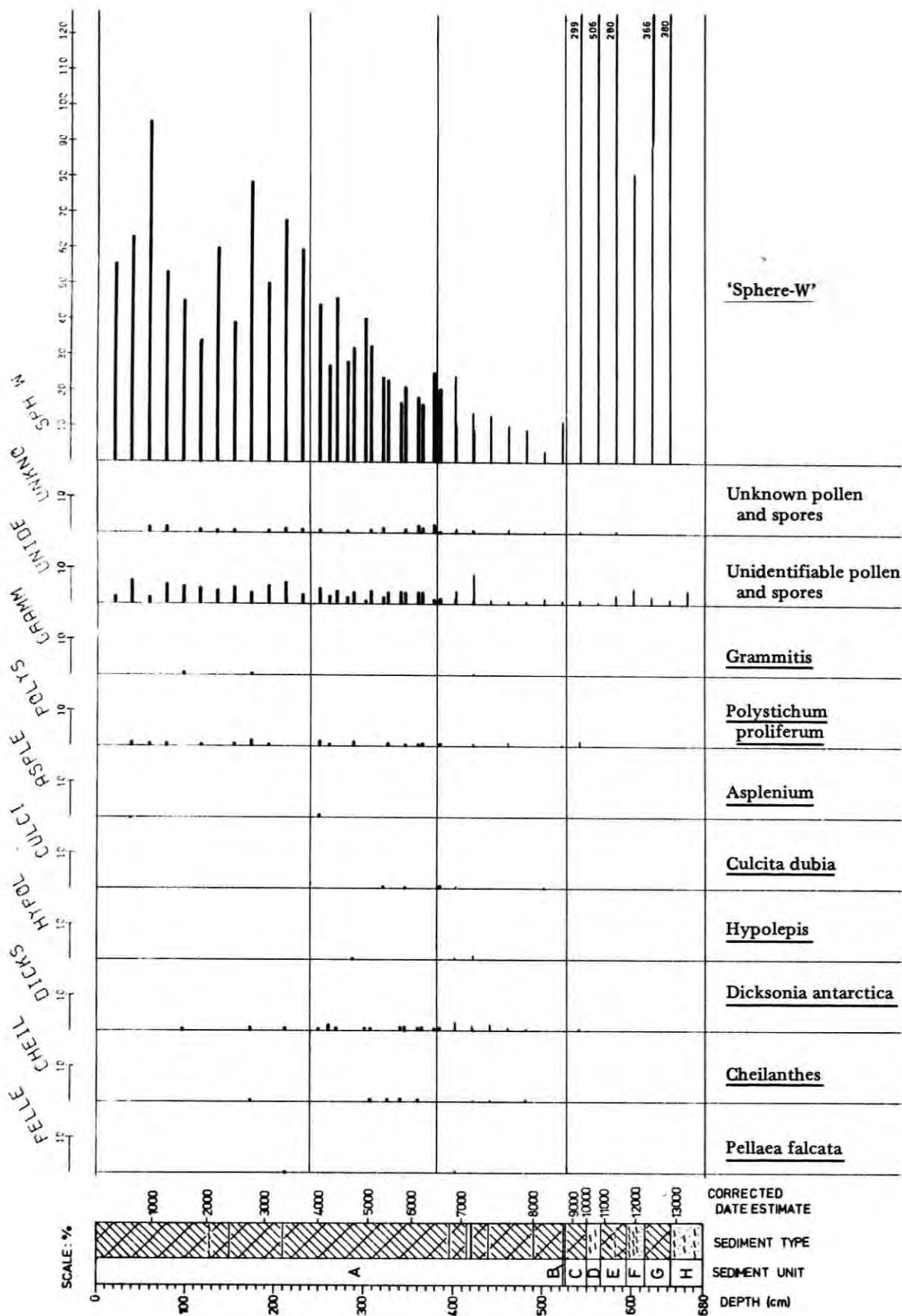


FIG. 3.11 continuation 6.

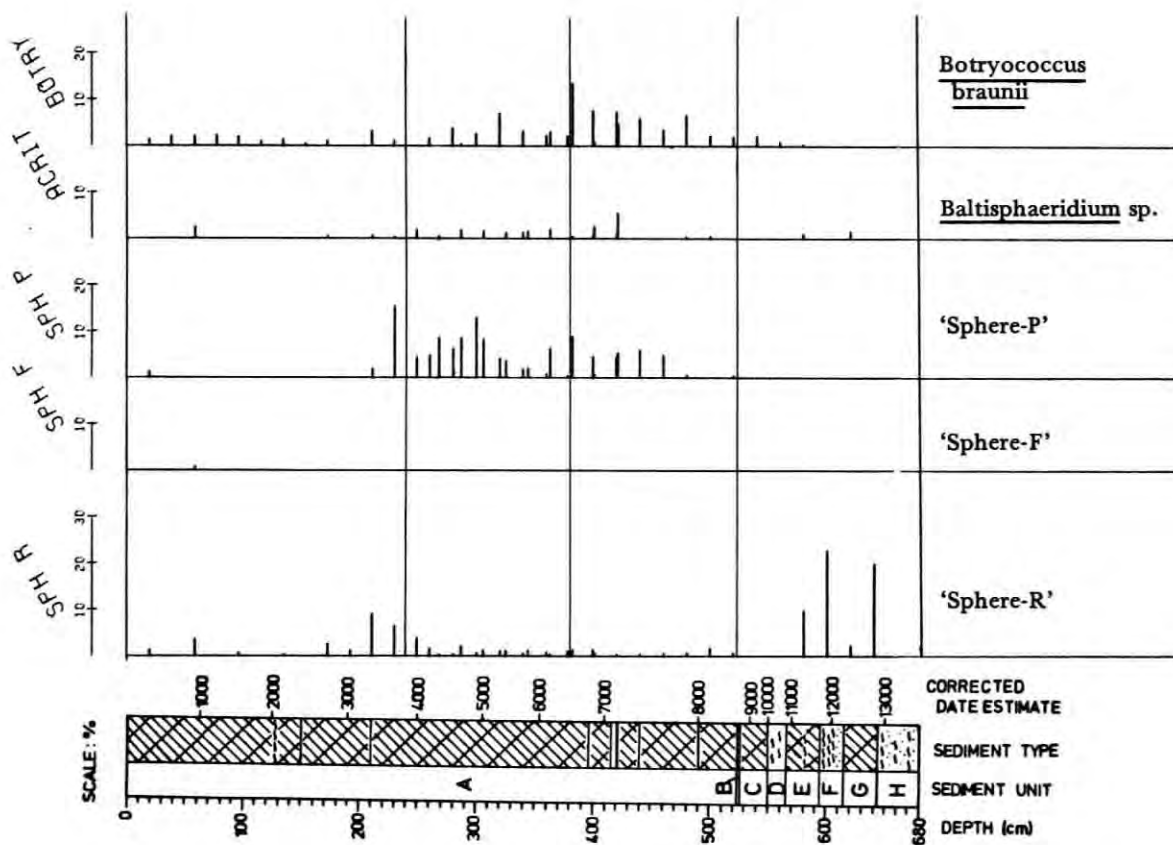


FIG. 3.11 continuation 7.

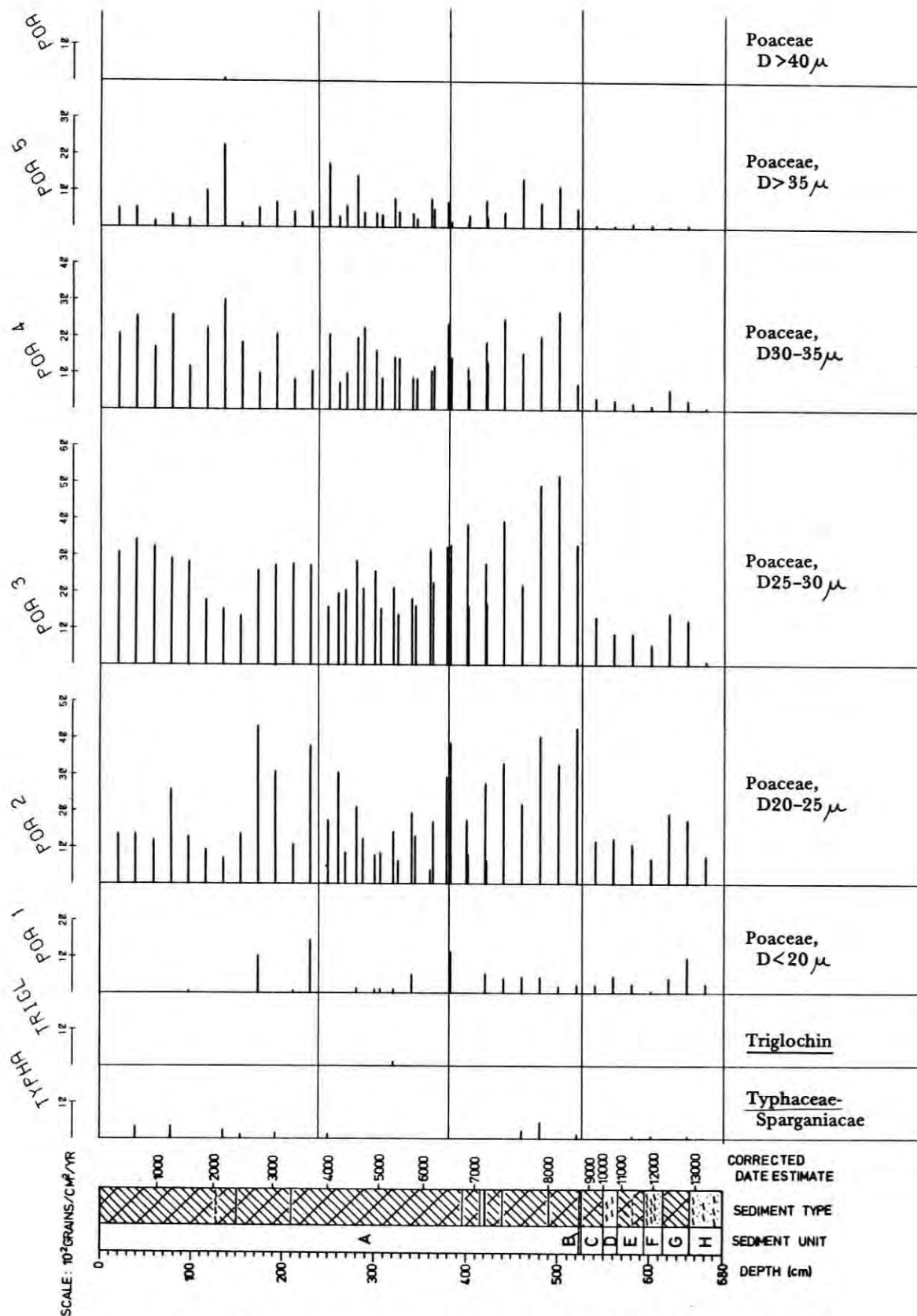


FIG. 3.12 BLUE LAKE POLLEN DEPOSITION RATE DIAGRAM

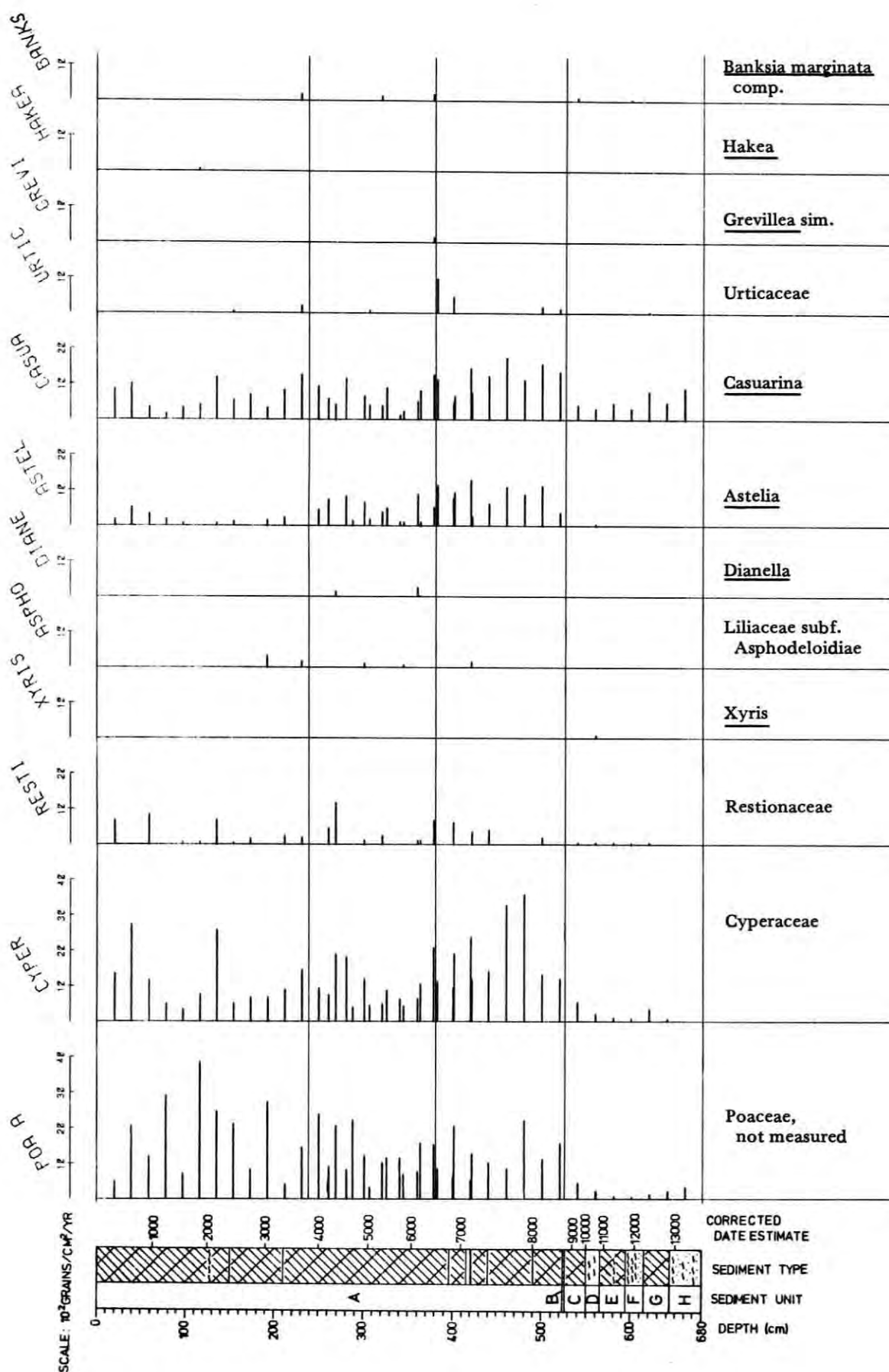


FIG. 3.12 continuation 1.

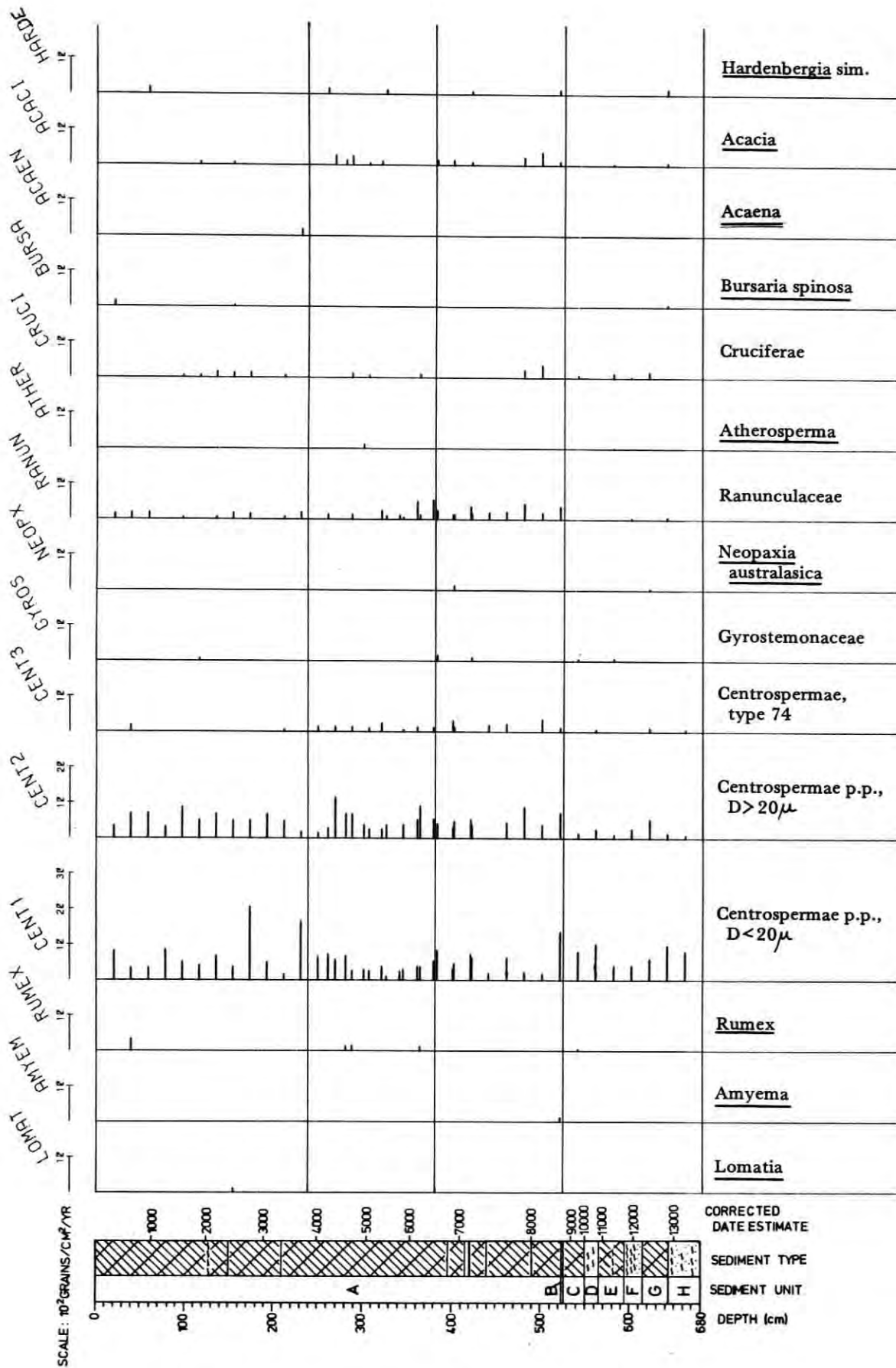


FIG. 3.12 continuation 2.

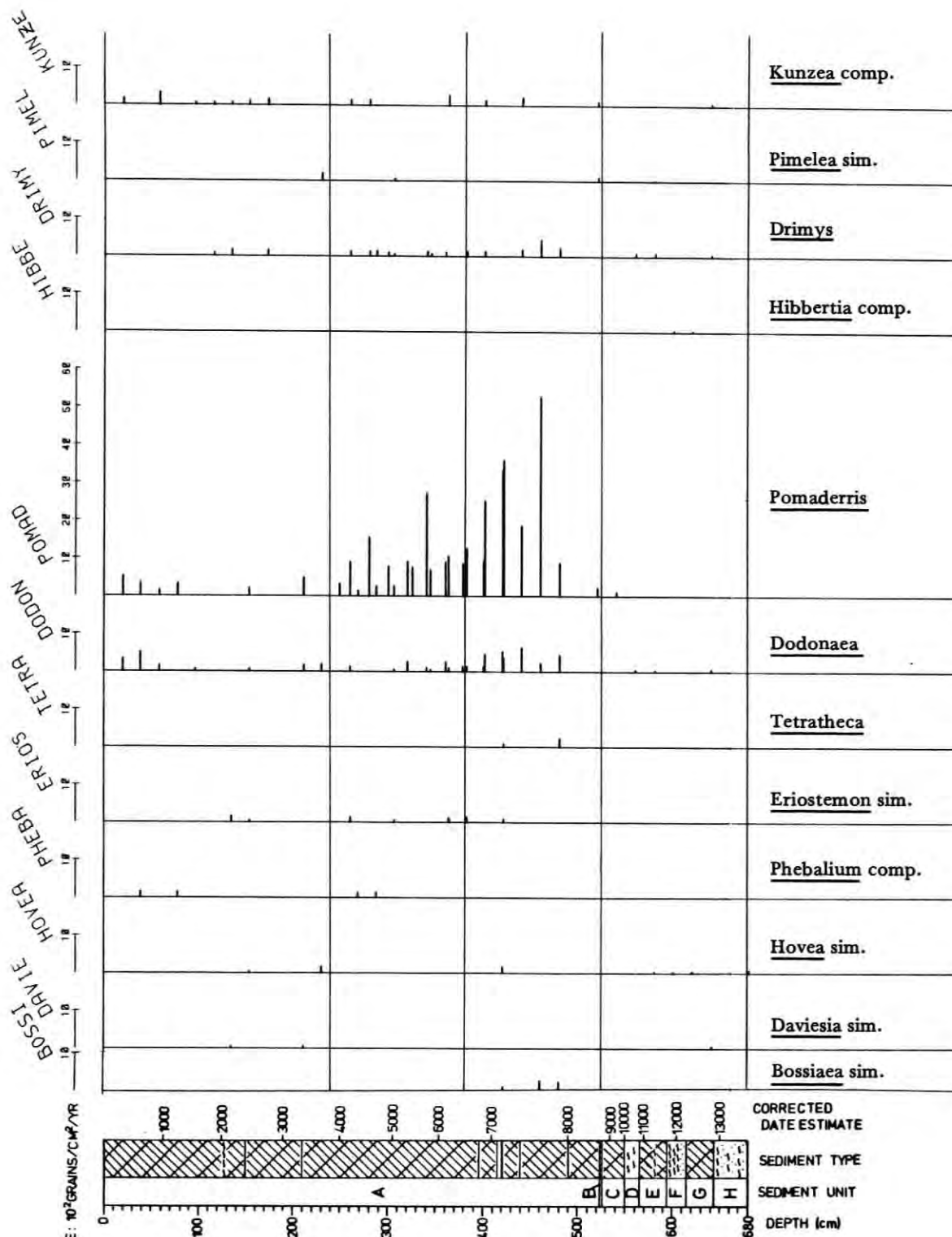


FIG. 3.12 continuation 3.

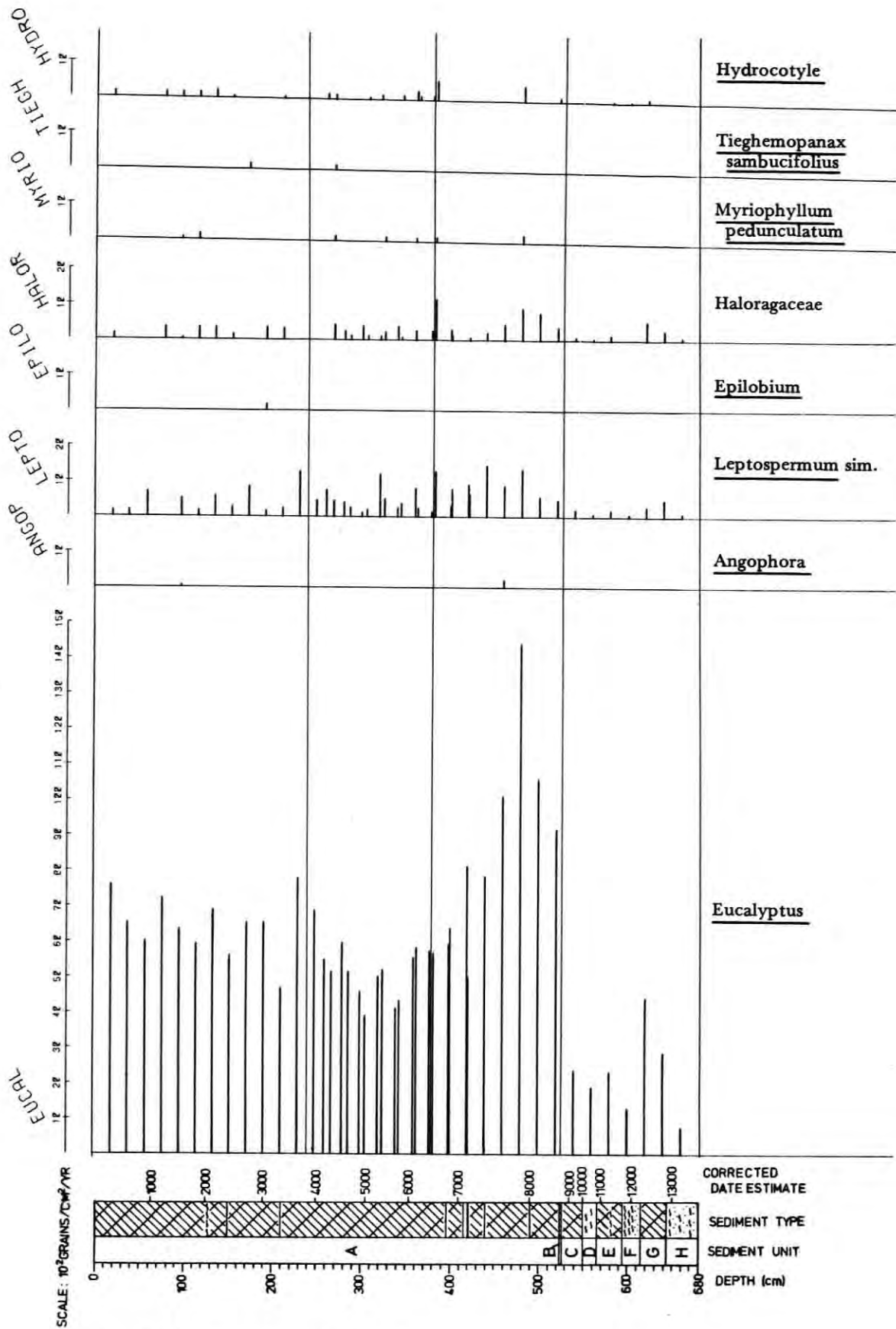


FIG. 3.12 continuation 4.

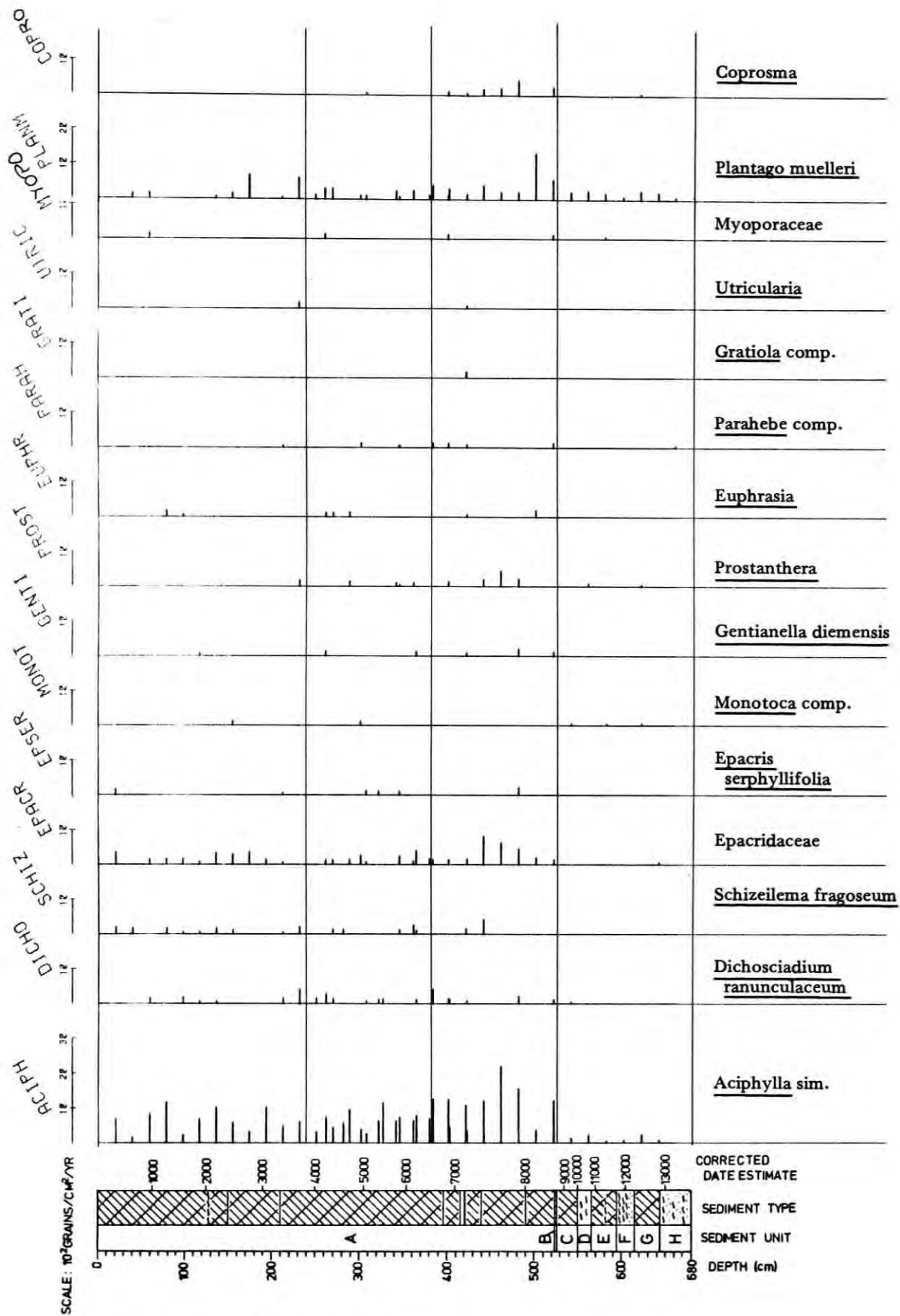


FIG. 3.12 continuation 5.

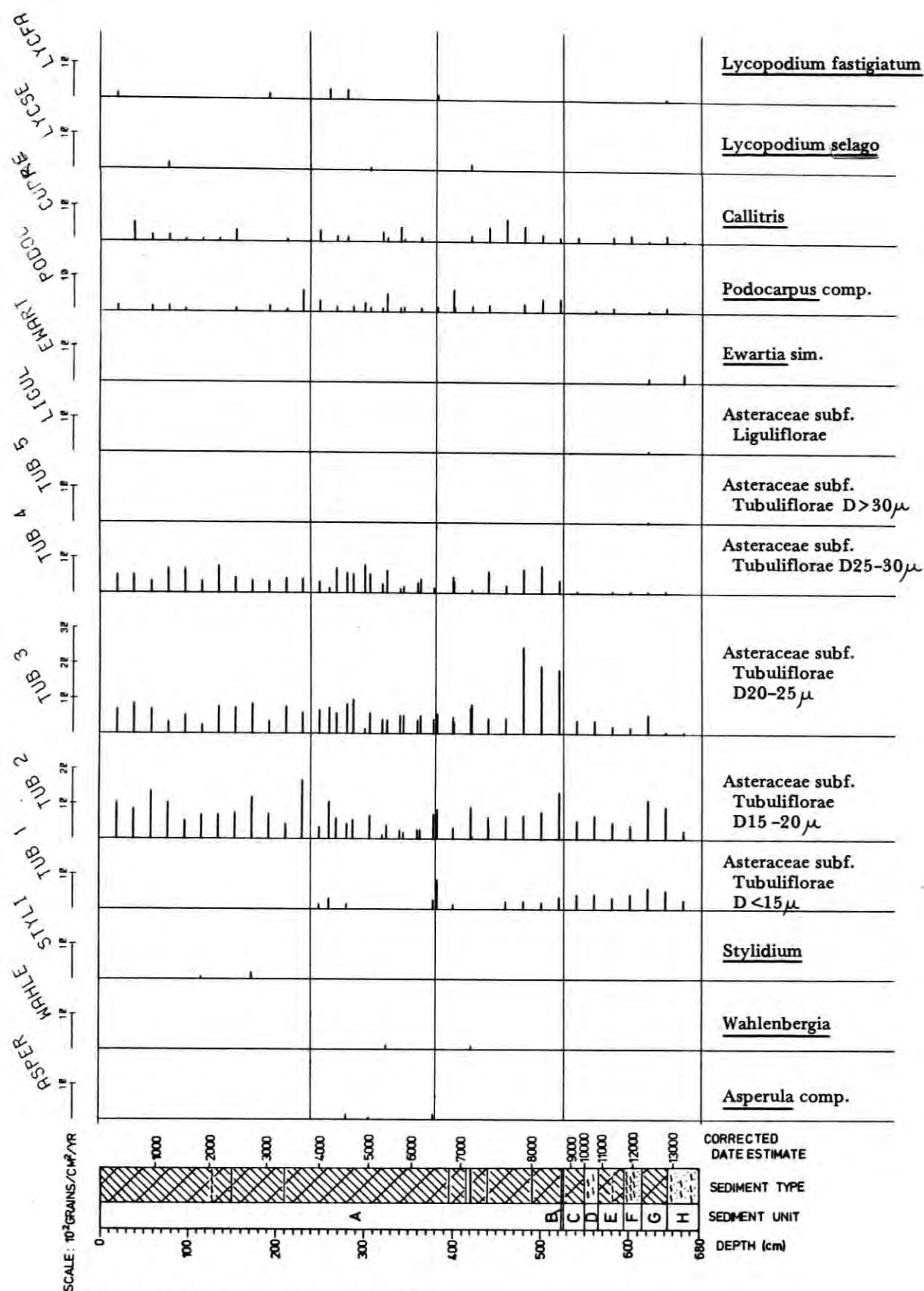


FIG. 3.12 continuation 6.

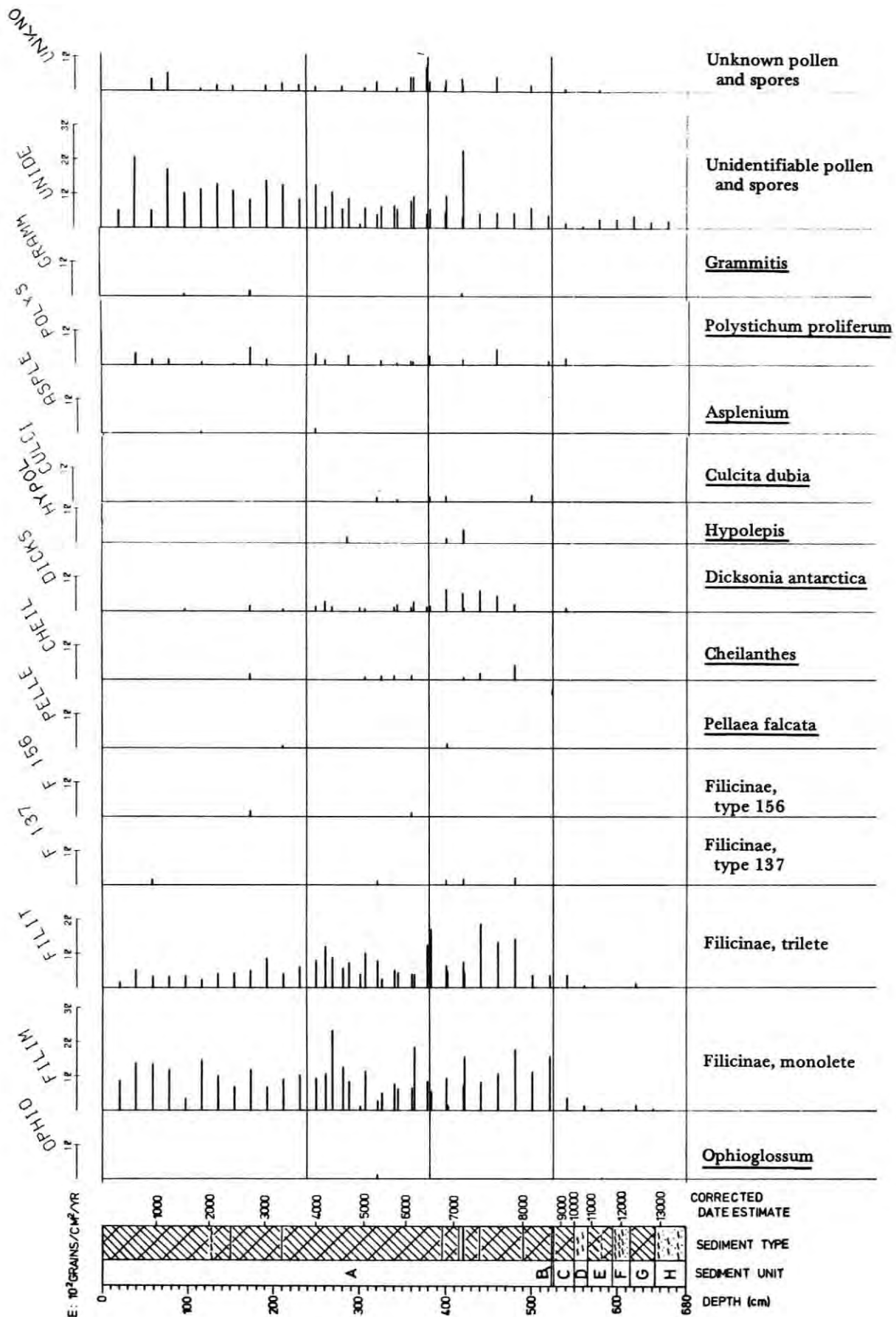


FIG. 3.12 continuation 7.

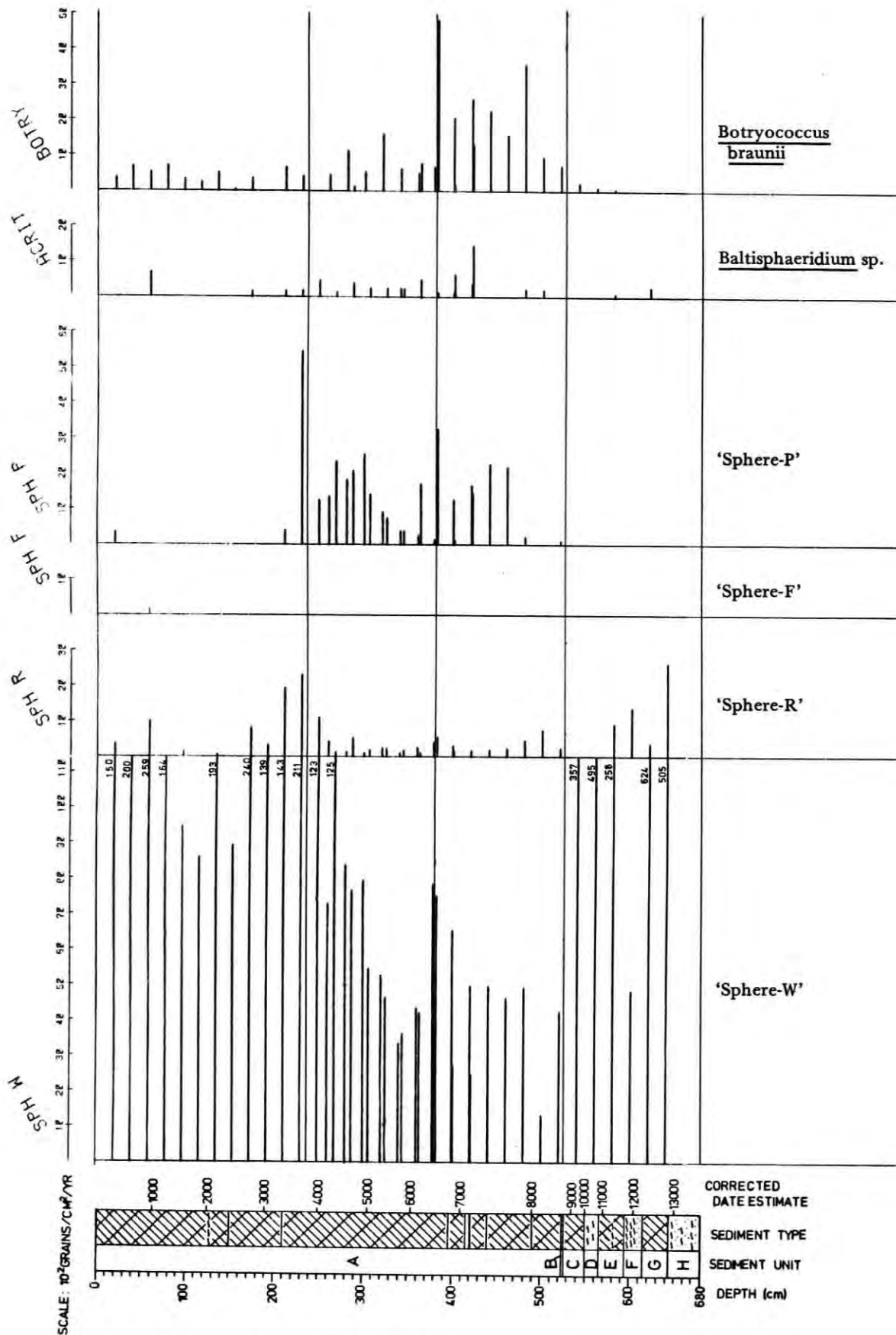


FIG. 3.12 continuation 8.

i) Windswept feldmark

This includes the Epacris 'microphylla', Epacris 'microphylla' - Veronica densifolia and Ewartia nubigena associations of McVean (1969), and the Epacris petrophila - Veronica densifolia alliance of Costin (1954).

The pollen record of these communities is poor. The only pollen taxon exclusively associated is Ewartia sim., which is confined in occurrence to the lower part of zone BL1, before 12000 years B.P. Other pollen taxa of which part may represent feldmark are Epacridaceae, Asteraceae ($D > 20\mu$), Poaceae and Parahebe comp. (which may include Veronica densifolia). None of these taxa show a similar pattern to Ewartia.

Helipterum albicans ssp. alpinum, an important component of McVean's Ewartia nubigena association, has a mean diameter of 20 to 25 μ . This group of Asteraceae ($D_{20-25\mu}$) increases in RPF and PDR in the basal part of zone BL1, reaching a pronounced peak in zone BL2, between 8700 and 7700 years B.P.

ii) Short alpine herbfield

This includes a variety of long snow-lie communities, including the Polystichum proliferum, Caltha-Dichosciadium, Oreobolus pumilis, Plantago muelleri - Conostomum curvirostre and Coprosma pumila associations of McVean and the Plantago muelleri - Montia australasica and part of the Brachycome nivalis - Danthonia alpicola alliances of Costin.

Exclusive pollen indicators of these communities include Neopaxia (Montia) australasica, Plantago muelleri, Schizeilema fragoseum and Dichosciadium ranunculaceum. Of these taxa, Neopaxia is poorly represented, Schizeilema and Dichosciadium appear at the top of zone BL1 or in BL2, while the better represented Plantago muelleri, though having greatest RPF through zone BL1, has a PDR peak at the base of zone BL2, between 9000 and 8000 years B.P.

Pollen taxa mainly referable to these communities include Ranunculaceae, Cruciferae (mainly Cardamine), Acaena, Polystichum (including a large part of monolete Filicinae), Epilobium and Haloragaceae. Acaena and Epilobium are poorly represented. Cruciferae are only slightly better represented and appear mainly in zones BL1 and BL2 between 12000 and 8000 years B.P. Haloragaceae occur through the diagram, having greatest PDR in the lower

part of zone BL2, between 8700 and 7600 years B.P. Ranunculaceae and Polystichum increase markedly at the base of zone BL2 in both PDR and RPF.

Pollen taxa partly referable to these communities include Centrospermae ($D > 20\mu$, which may include Colobanthus), Cyperaceae, Aciphylla sim. (which includes Oreomyrrhis), Coprosma and Asteraceae. These exhibit similar trends to the above taxa, but are probably best assigned to other communities, with the exception of Centrospermae.

- iii) Tall alpine herbfield - Short tussock grassland. This includes the Poa caespitosa - Celmisia longifolia, Celmisia longifolia and Danthonia frigida associations of McVean and the Poa caespitosa - Danthonia nudiflora and Celmisia longifolia - Poa caespitosa alliances of Costin.

Pollen taxa mainly referable to these plant communities include Rumex, Hydrocotyle sim., Aciphylla sim., Gentianella diemensis, Euphrasia, Wahlenbergia, Stylidium and Liliaceae subfamily Asphodeloideae. Aciphylla is the only reasonably common pollen type of these: it increases abruptly in both RPF and PDR at the base of zone BL2, reaching a peak in PDR at about 7600 years B.P.

The major components of these communities belong to the Asteraceae and Poaceae. Unfortunately, these families are important in sclerophyll forest, woodland, and other communities at all elevations. The dominants (Craspedia uniflora and Celmisia longifolia have pollen grains with mean diameter between 25 and 35 μ , however: these size ranges of Asteraceae have low RPF and PDR in zone BL1, increasing at the base of unit BL2.

- iv) Groundwater communities

a) Bogs

These include the Baeckea gunniana - Richea continentis and Sphagnum - Richea - Astelia associations of McVean and the Epacris serpyllifolia - Kunzea muelleri and Epacris paludosa - Sphagnum cymbifolium alliances of Costin.

Exclusive pollen indicators of these communities are the obligate alpine genus Astelia, and Epacris

serpyllifolia. The latter is too rare a pollen type to make definite conclusions, but does not appear in zone BL1. Astelia has its first record at about 10500 B.P. in zone BL1, but increases greatly in RPF and PDR at the base of zone BL2, decreases to slightly lower levels through zone BL3, then is rare between 3700 and 1500 years B.P., after which it appears to increase slightly.

Pollen taxa mainly attributable to these communities include Restionaceae, Epacridaceae and Lycopodium fastigiatum. Each taxon is represented in all zones; Epacridaceae is rare in zone BL1, reaches a peak in PDR in zone BL2, between 8000 and 7300 years B.P., after which it declines to more or less constant levels.

The pollen taxon Leptospermum sim. may include the association codominant Baeckaea gunniana: it follows a similar trend in PDR to Epacridaceae.

b) Fens

These include the Carex - Drepanocladus association of McVean and the Carex gaudichaudiana and Carex gaudichaudiana - Sphagnum cymbifolium alliances of Costin.

Exclusive pollen indicators of these plant communities are Myriophyllum pedunculatum and Utricularia. Both are rare; neither occur in zone BL1.

Cyperaceae occur in other plant communities of moist habitats but are probably mainly referable here. Pollen appears in the second sample of zone BL1 (c.12800 years B.P.), and increases slightly in RPF and PDR towards the top of the zone. This trend is continued in zone BL2, PDR peaking at about 7700 years B.P., after which there is a slight decline in frequencies, which are rather erratic, possibly because of varying preservation.

Typha and Triglochin are taxa of similar plant communities at lower altitudes. Both pollen types are rare.

v) Tall heath

This includes the Phebalium ovatifolium and Podocarpus lawrencei associations of McVean and the Oxylobium - Podocarpus alliance (excluding the Kunzea muelleri association) of Costin. Closely allied plant communities form an understory to Eucalyptus pauciflora woodland in many places, while some genera extend to the upper zones of wet sclerophyll forest.

Exclusive pollen indicators of these communities include Phebalium comp., Podocarpus comp. and Lycopodium selago. Phebalium and Lycopodium selago are rare taxa. Podocarpus is not frequent, but appears to show higher PDR in zones BL2 and BL3.

Pollen taxa mainly referable to these plant communities include Bossiaea sim., Hovea sim., Drimys, Coprosma, Prostanthera and Parahebe comp. These are of sporadic occurrence in the diagrams, except for Coprosma which peaks in zone BL2.

Pollen taxa partly referable are Grevillea sim., Acacia, Pimelea, Epacridaceae and Asteraceae.

vi) Short heath

This includes McVean's Kunzea muelleri association and the Kunzea muelleri association of Costin's Oxylobium ellipticum - Podocarpus alpinus alliance. This community occupies wind-swept spurs and ridges between 1800 and 2000 m, as well as occurring marginally to sub-alpine cold air plains.

Although present in the tall heath communities, Kunzea is far more abundant in the short heath. The pollen record is sparse, the taxon apparently being frequent in zone BL4, for the last 3000 years.

Other pollen taxa partly representing this community are Grevillea sim., Prostanthera, Asteraceae ($D > 25\mu$) and Poaceae.

vii) Forest and woodland

This includes subalpine woodland of Costin's Eucalyptus niphophila alliance, wet sclerophyll forest of the E. delegatensis - E. dalrympleana and E. fastigata - E. viminalis alliances, dry sclerophyll forest of the E. macrorhyncha - E. rossii alliance, savannah woodland of the E. pauciflora - E. stellulata alliance, and possibly other woodland communities not now represented in the area.

a) Pollen taxa referable to all subformations

These include Poaceae, Grevillea sim., Acacia, Tetratheca, Hibbertia comp., Pimelea sim., Eucalyptus and Asteraceae. Of these, only Tetratheca, Hibbertia and Eucalyptus are confined to forest and woodland, although Acacia is practically so. Tetratheca and Hibbertia are rare and confined to zones BL2 and BL1 respectively.

Eucalyptus RPF varies between 15 and 30% through the diagram, being lowest in the oldest sample, because of the relatively high proportion of Casuarina. Examination of the PDR diagram shows a much more dramatic variation, in close agreement with the trend of total PDR. Minor peaks in zone BL1 correspond to the more organic rich sediment units G, E and C. PDR increases greatly at the base of zone BL2, peaks at about 8000 years B.P., then declines to a temporary minimum in zone BL3 before rising to the top of the zone. In zone BL4 a slight decline at the base of the zone (about 3300 years B.P.) is followed by probably mere statistical fluctuations.

Acacia is most frequent in zones BL2 and BL3.

b) Pollen taxa referable to wet sclerophyll forest.

Exclusive taxa include Dianella, Urticaceae, Lomatia, Atherosperma, Eriostemon sim., Pomaderris, Tieghemopanax, and the bulk of the ferns: Filicinae types 137 and 156, Pellaea falcata, Cheilanthes, Dicksonia antarctica, Hypolepis, Culcita dubia, Asplenium and Grammitis. Of these, Pomaderris and Dicksonia are the only reasonably common taxa. Most of the others, particularly the ferns, appear to be most frequent in zones BL2 and BL3, allowing for the increased number of samples in this interval. Pomaderris, probably mainly Pomaderris aspera largely found in shady moist stands of the Eucalyptus fastigata - E. viminalis alliance, appears in the uppermost part of zone BL1, increases greatly in zone BL2, at about 7700 years B.P., declines erratically through zone BL3, and is rare in zone BL4, from the base at about 3800 years B.P. There may be a slight increase in frequency since about 1200 years B.P. The PDR trend is similar to the RPF one, the peak in zone BL2 being emphasized. Dicksonia follows a similar pattern to Pomaderris, but does not appear to increase in the most recent zone.

Trilete Filicinae are mostly referable to wet Sclerophyll forest, but the taxon includes Pteridium esculentum, a species common in both dry and wet sclerophyll forest, at lower elevations, after disturbance. A broadly similar trend to that of Pomaderris is seen in the diagrams, variation being less extreme.

Pollen taxa partly referable are Ranunculaceae (which includes Clematis), Hovea sim., Drimys, Leptospermum sim., Haloragaceae, Hydrocotyle sim., Epacridaceae, Prostanthera, Parahebe comp., Gratiola comp., Coprosma, Asperula comp., Stylidium and Polystichum (including part of monolete Filicinae). Several of these taxa appear to follow different trends to the taxa described above.

c) Pollen taxa referable to dry sclerophyll forest

These include Hardenbergia sim., Daviesia sim., Banksia marginata comp., Hakea, Dodonaea, Amyema, Monotoca comp. and Bursaria spinosa. Of these, Dodonaea and Bursaria are mainly confined to riparian habitats: Dodonaea follows a similar trend to Pomaderris (above). The other taxa are rare, and occur in all zones. Thus the pollen record is poor.

viii) Communities not now represented in the Snowy Mountains-Geehi area.

Unassigned pollen taxa include Casuarina, Callitris, Centrospermae, and the rare taxa Gyrostemonaceae, Xyris, Myoporaceae and Angophora. Callitris counts are unreliable.

Casuarina species in inland south eastern Australia at present include C. cunninghamiana, a tree restricted to river flats below about 800 m altitude and with a southern limit of distribution approximately 50 km north of the Snowy Mountains; C. nana, a shrub of sandstone plateaux nearer the coast; C. luehmannii of slopes and plains west of the mountains; and C. stricta, of dry stony habitats in the lower ranges. All appear to be associated with poor soils, and seem to be limited by temperature to altitudes below about 1000 m. Casuarina RPF is high in the lowest sample, after which it fluctuates about low values. Calculation of PDR reduces the frequency in the lowest sample to a value comparable with the rest of zone BL1. PDR increases at the base of zone BL2 (8700 years B.P.); after 7000 years B.P. it fluctuates greatly about lower values.

Centrospermae, type 74 is probably to be attributed to the Caryophyllaceae and thus to wet sclerophyll forest. It follows a similar trend to other forest taxa such as Dicksonia, but occurs with greater frequency in zone BL1.

Centrospermae, $D > 20\mu$, has been partly attributed to Colobanthus, the remainder, with Centrospermae, $D < 20\mu$, probably mainly comprises Chenopodiaceae. These occur at present in low rainfall (50cm) areas of the tablelands, but are most common in the semi-arid areas to the west of the mountains. Although erratic high values occur higher in the diagram, peak RPF and PDR clearly occur through zone BL1.

Gyrostemonaceae and Myoporaceae are now also mainly to be found in semi-arid areas to the west. Both occur sporadically through the sequence.

ix) Lake plankton

Few conclusions can be drawn from these taxa in the absence of ecological evidence, but periods of apparent stability and of change in the hydrological conditions, for example in water temperature and nutrient supply are probably reflected in their stratigraphic record.

These periods are:

>13000 yrs. B.P.: plankton not recovered.

c. 13000-8700 yrs. B.P. (i.e. rest of zone BL1): high values of 'Sphere-W' and 'Sphere-R', with appearance of Baltisphaeridium and Botryococcus.

c. 8700-7800 yrs. B.P.: low deposition rate of 'Sphere-W' slight peak in 'Sphere-R', beginning of higher rates for Botryococcus.

c. 7800-6400 yrs. B.P.: greatly increased deposition rate of 'Sphere-P', high rate for Botryococcus, intermediate values for 'Sphere-W'.

c. 6400-3600 yrs. B.P.: after an initial drop, general increases in sedimentation rates of 'Sphere-W' and 'Sphere-P'.

c. 3600- recent: initial peak in 'Sphere-R', between 4000 and 3000 yrs. B.P., perhaps associated with a single-sample, therefore dubious peak in 'Sphere-P'. After this, 'Sphere-P' virtually disappears, and there is little change from 3000 yrs. B.P. to present, except for a slight minimum in the 'Sphere-W' curve at about 2000 yrs. B.P.

It may be noticed a) that calculation of PDR has brought 'Sphere-W' deposition rates in zone BL1 closer to recent values, although still apparently higher, and b) that times of change in the plankton curves are similar to those of various pollen taxa.

TWYNAM CIRQUE

This cirque is situated to the north of Blue Lake, separated from it by the Crummer spur of Mt. Twynam (see figure 3.13). It was investigated because radiocarbon dates obtained by Costin (1972) indicated the possibility of extending the pollen analysed sequence back to 20000 years B.P., with overlap between the Blue Lake and Twynam Cirque sequences.

The head of the cirque contains the most persistent and geomorphically active of the semipermanent snowpatches of the mountains (Costin, Jennings, Black and Thom, 1964). Snowpatch peats (derived from short alpine herbfield) near the head of the cirque have been dated by Costin (l.c.) at 2500 years B.P., indicating the duration of the present snowpatch regime. The peats are underlain by fresh bedrock, suggesting that the snowpatch was more persistent before 2500 years ago.

The pollen analysis site is situated further down the valley, but within the terminal moraines (see figure 3.13). Stratigraphy of the site has been discussed by Costin (l.c.). The deposits are exposed along the side of a creek which drains a fen, probably formerly a shallow lake before the moraine dam was breached. Overlain by 30-70 cm of peaty soil, the deposits consist of more than a metre of laminated gray clay, silt, sand and some gravel. An unknown depth of gravelly sand occurs below. The laminated deposits do not appear to be glacial varves, but are probably snow-melt deposits (Galloway and Ericksson, 1971).

Radiocarbon dates obtained by Costin were:

Base of acid fen peat NZ-400 8,620 ± 180 years B.P.

Top of laminated deposits NZ-436 8,650 ± 990 "

Base of laminated deposits NZ-436 20,200 ± 165 years B.P.

The reported ages are based on the 5570-year C-14 half-life: corrected age (from figure 3.7, this chapter) for the 8650 years B.P. date is 8790 years B.P.

Stratigraphy at the sampled site is illustrated in Plate 3.1. Samples were taken with plastic vials from the positions indicated; processing methods are outlined in Chapter 2.

The Pollen Diagram

Although pollen concentration figures were calculated for each of the samples, there is inadequate information to

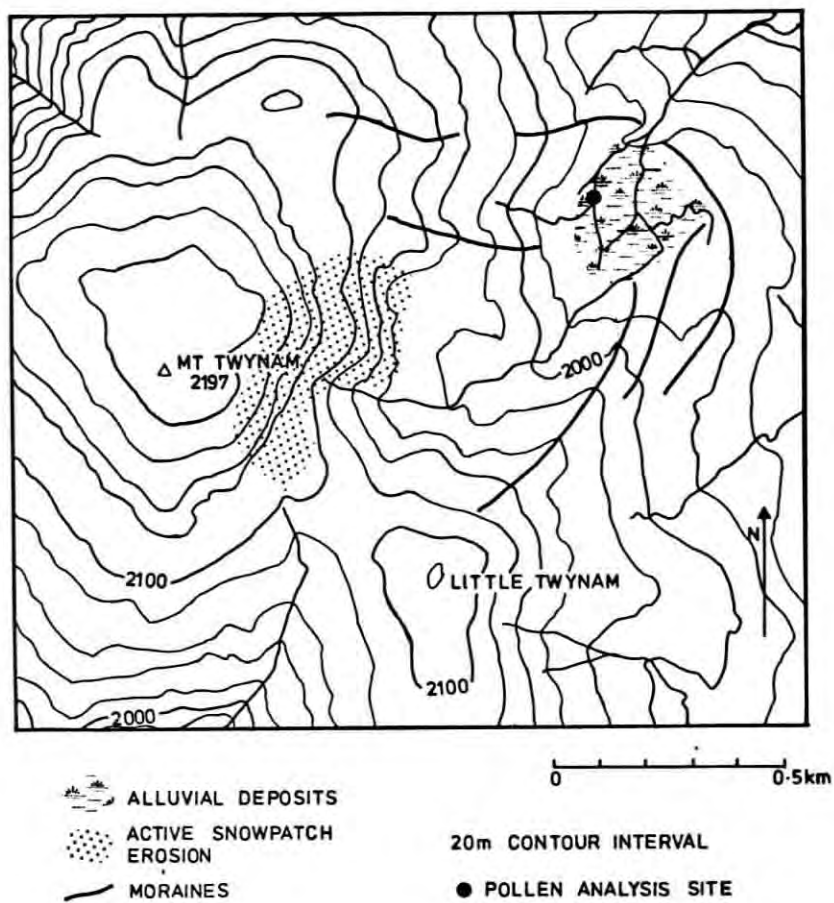
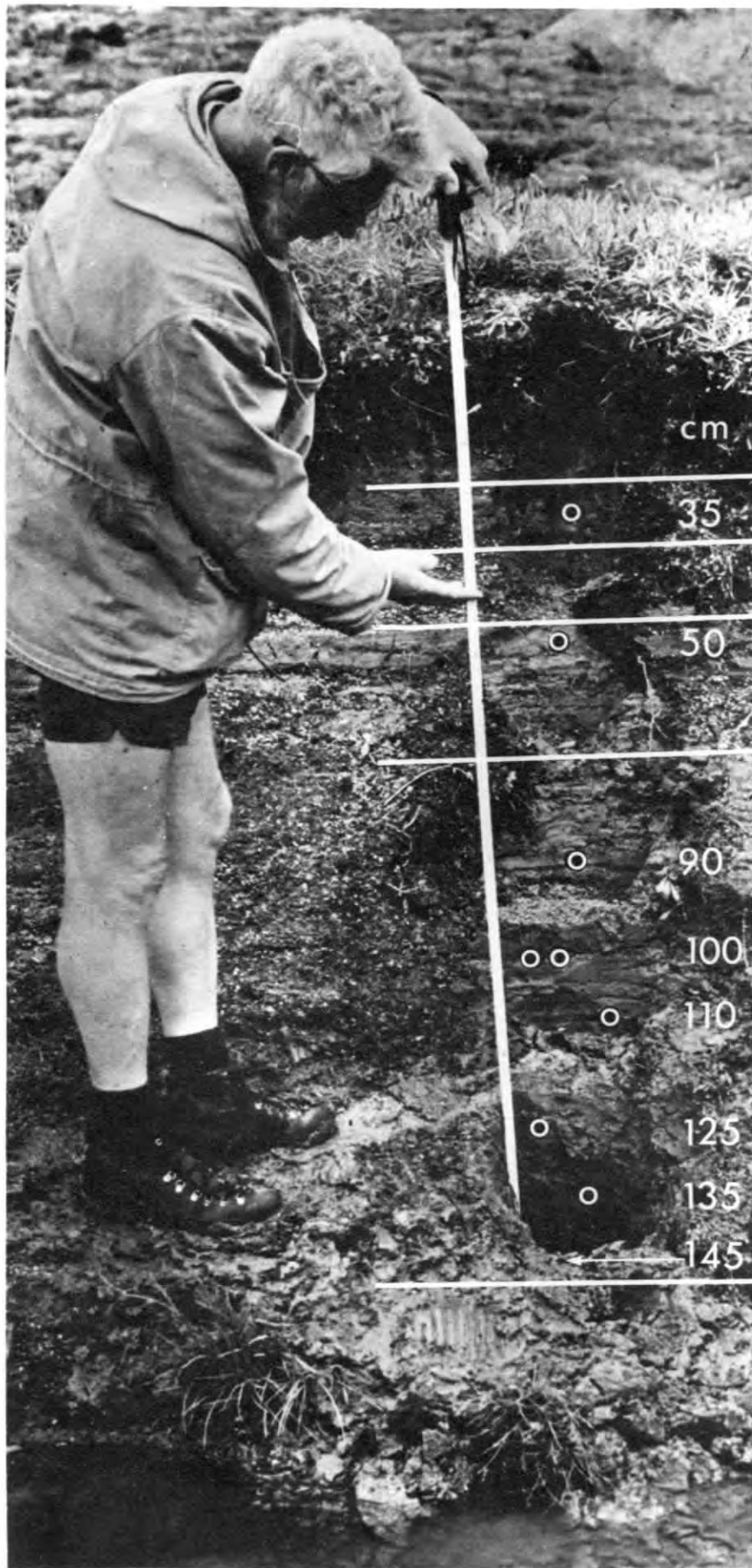


FIG. 3.13 TWYNAM CIRQUE



Celmisia - Poa
Herbfield

Alpine humus soil,
gravelly near
base

cm

Clay & sand

o

35

Sand
orange clay layer

o

50

Clay with gravel
bands

orange clay layer

o

90

Laminated clay
with silt bands

o o

100

o

110

o

125

o

135

145

Gravel
(at stream level)

produce sedimentation rate curves. Thus only an RPF diagram is presented (figure 3.14). Details of the pollen counts and pollen concentration are given in Appendix D, Table D.4.

Features of the diagram include:

- i) Increasing RPF of Cyperaceae and Aciphylla sim.
- ii) High proportion of Casuarina and Centrospermae ($D < 20\mu$) in the lower set of samples.
- iii) High relative frequency of smaller grains of Poaceae and Asteraceae, through the diagram.
- iv) Occurrence of Ewartia sim. in the lower samples.
- v) Low RPF of Filicinae and forest taxa.

These features suggest a correlation of the Twynam Cirque 90 cm level with the lowest (660 cm) sample from Blue Lake. The two Twynam Cirque samples above this level appear to correlate with the upper part of zone BL1, and this is in agreement with the radiocarbon ages.

A further feature of the diagram is the peak in Cruciferae at 100 cm. Cardamine spp. are important components of stands of short alpine herbfield in the crags above Blue Lake. The high proportion suggests local occurrence in the Twynam Cirque, beginning at about 16500 years B.P. and peaking at about 15500 years B.P. (based on interpolation between radiocarbon dates).

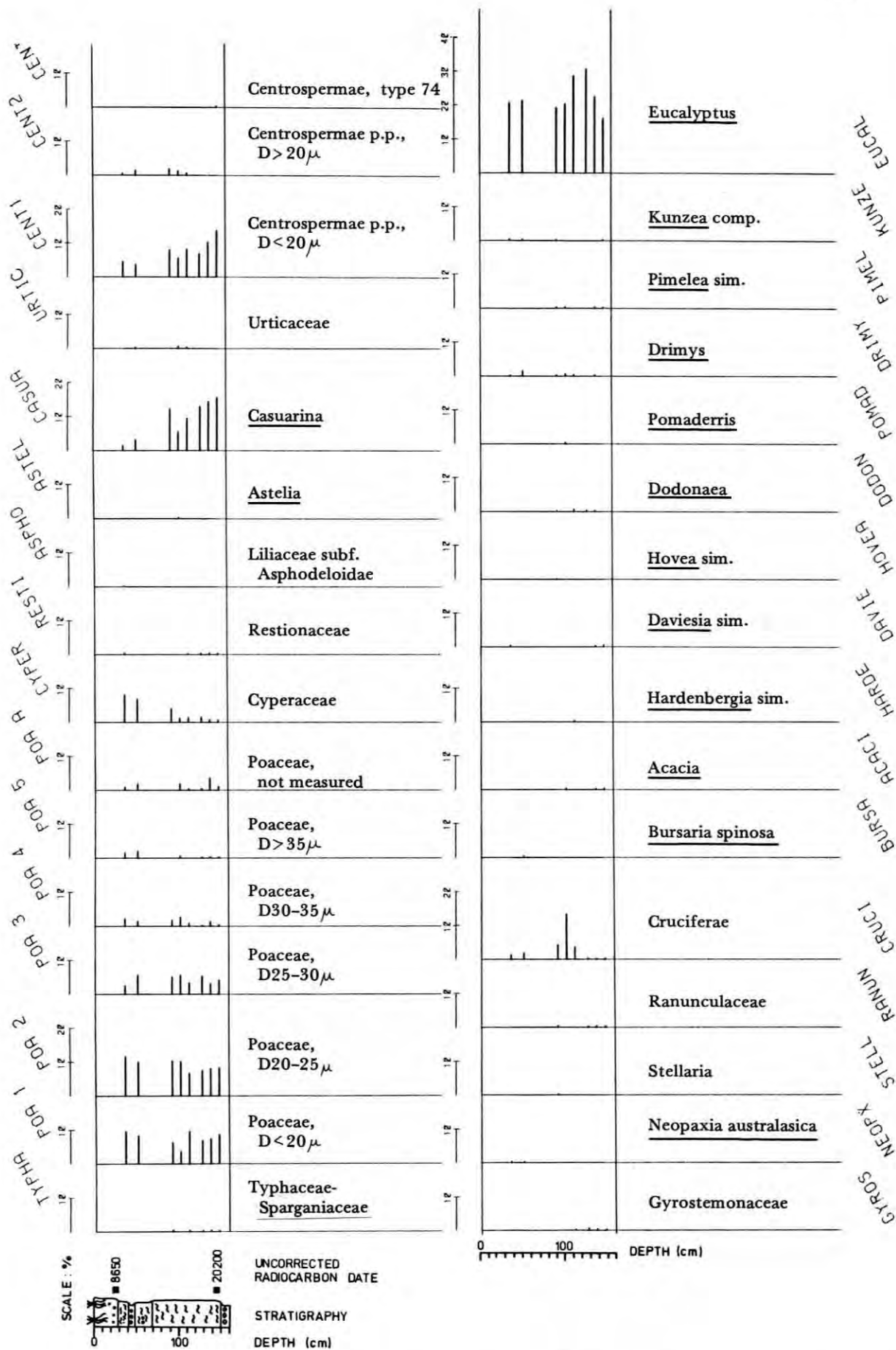


FIG. 3.14. TWYNAM CIRQUE RELATIVE POLLEN FREQUENCY DIAGRAM.

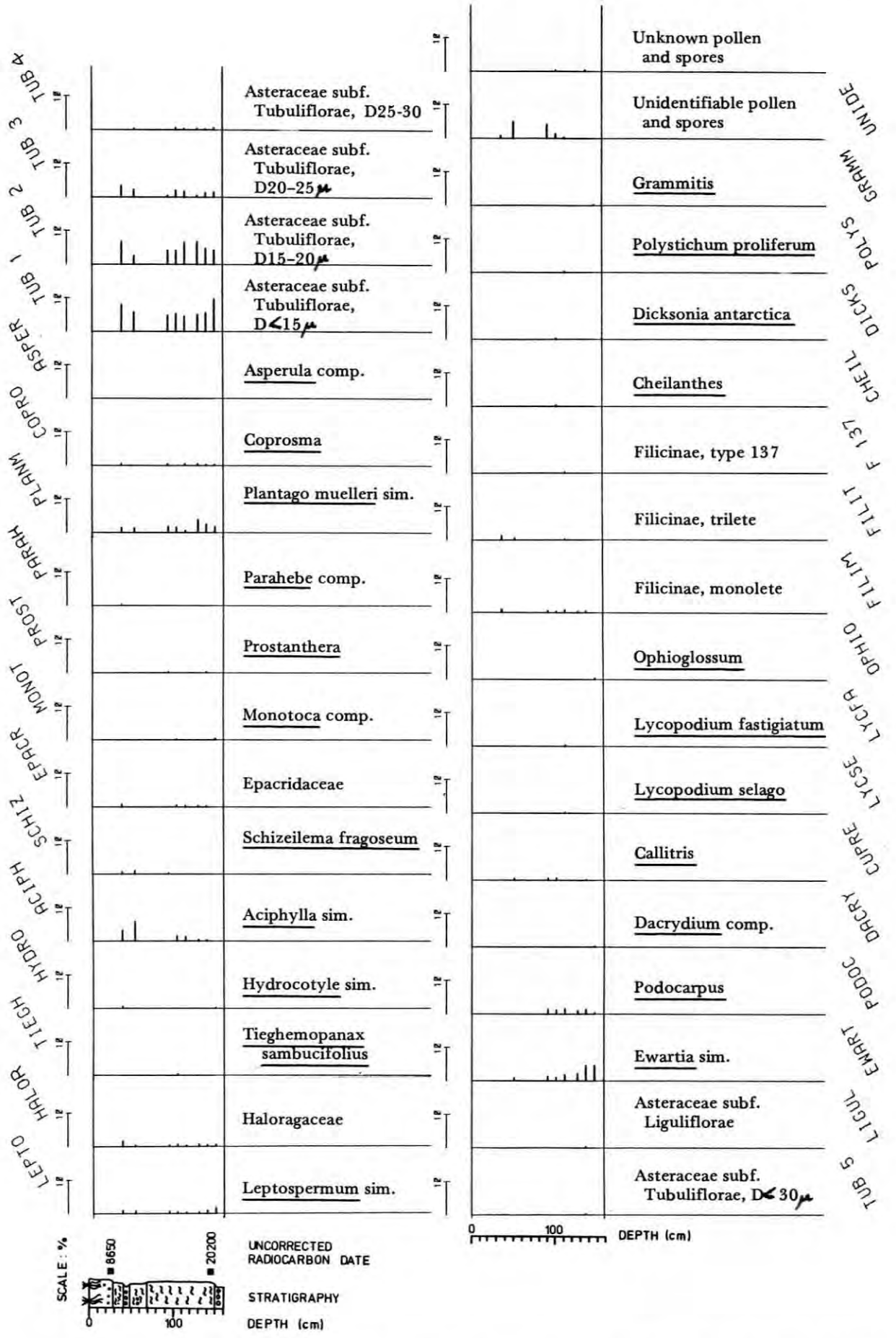


FIG. 3.14. TWYNAM CIRQUE RELATIVE POLLEN FREQUENCY DIAGRAM (continuation 1).

Discussion

Five pollen zones have been recognized, either explicitly or implicitly. The oldest of these, which shall be termed TC for the purposes of discussion, consists of the lowest sample of the Blue Lake diagram and the lowermost 6 samples of the Twynam Cirque diagram. The others are the remainder of zone BL1, and zones BL2 - BL4. Pollen analytical characteristics of these zones are summarized below.

i) zone TC (c. 20000-13000 yrs. B.P.)

High levels of Casuarina, Centrospermae ($D < 20\mu$), Poaceae ($D < 20\mu$), Asteraceae ($D < 20\mu$) and Podocarpus, in relative terms, thus greater representation of non-alpine taxa. The Blue Lake PDR diagram shows that actual PDR of these taxa may not have been higher than in the succeeding sample, but argument from a single sample is dangerous. The only pollen taxa of apparent alpine plant community origins which have higher relative frequencies are Ewartia sim. and Cruciferae. The former, if identified correctly, indicates the presence of feldmark, the latter suggests increase in abundance of short alpine herbfield, perhaps of a rather specific type, towards the close of the period.

ii) Zone BL1 (c. 13000-8700 yrs. B.P.)

Casuarina decreased in RPF, although PDR may not have decreased. Fluctuations in total PDR may have occurred, but the control on sedimentation rate is insufficient to confirm this. Short alpine herbfield taxa had their highest RPF in the sequence, although PDR peaked slightly higher, at the base of the next zone. PDR and RPF of fen community plants increased through the zone.

iii) Zone BL2 (c. 6500-8700 yrs. B.P.)

There was a great increase in total pollen deposition rate, and most taxa showed corresponding increases. Those which did not included Centrospermae ($D > 20\mu$) and Asteraceae ($D < 15\mu$). Alpine and common forest taxa increased at the base of the zone, whereas wet sclerophyll forest taxa, mainly Pomaderris and Dicksonia

- increased slightly later, at about 7700 years B.P.
- iv) Zone BL3 (c. 3800-6500 yrs. B.P.)

Total pollen deposition decreased at the base of the zone, and most taxa showed corresponding decreases. Pomaderris declined markedly in RPF, although there was one erratic high frequency, while other taxa had more or less constant RPF.

- v) Zone BL4 (c. present - 3800 yrs. B.P.)

Pomaderris and Astelia declined markedly in RPF and PDR at the base of the zone, both possibly increasing after 1500 yrs. B.P.

Changes in pollen deposition rate without associated changes in relative pollen frequencies must be treated with suspicion, as possibly arising from undetected fluctuations in sedimentation rate. However all the changes mentioned above are supported by RPF variations. The question remains whether these changes in RPF could be due to differential pollen sedimentation changes associated with changes in sedimentation rate of inorganic sediment.

It is difficult to visualise any such changes in sedimentation regime not ultimately due to climatic factors. The possibility of differential pollen deposition is considered in Chapter 4. Assuming for the moment that the observed fluctuations in PDR reflect changes in relative abundance of plant communities, the following interpretation of vegetation history may be made.

Before about 17000 years B.P. there was little local vegetation. Forest and herbfield communities were distant, and because of this the relative proportion of pollen derived from still more distant communities could be expected to be greater (Tauber, 1965). Feldmark vegetation may have been relatively important, and possibly local.

At about 13000 years ago, Eucalypt forest may have approached closer, or there may have been a replacement of areas dominated by Casuarina with a vegetation type either dominated by Eucalyptus or by taxa not well represented in the pollen diagrams. From the low relative frequency of the higher and intermediate size ranges of Asteraceae pollen, alpine herbfield in its present form would not appear to have been important in the vegetation. The most likely source of the small size range most frequent is certain sclerophyllous shrubs (Cassinia, Helichrysum, Olearia).

At about 8700 years ago forest vegetation appears to have approached the site rapidly. Alpine bog, fen, and herbfield also seem to have increased in importance. Although apparently poorly represented, the relative frequency of subalpine woodland understorey shrub taxa does not appear to have increased, thus it does not appear that woodland or forest vegetation surrounded the lake. The change in sediment character suggests greater organic production in the lake, although there are conflicting trends in the plankton taxa. Combined with the pollen evidence, this suggests a rise in mean annual temperature at this time.

From 7700 to 6600 years B.P. wet sclerophyll forest of lower altitudes appears to have been represented in the pollen diagram at higher levels than recently. This does not seem to have been due to a general rise in the levels of all vegetation zones, as alpine communities are still well represented, and the Eucalyptus frequency does not peak in the same manner as Pomaderris, the major wet sclerophyll forest indicator taxon. Astelia frequency is also high as is that of other alpine bog and fen taxa, suggesting that an increase in available moisture, possibly through higher precipitation, may have been responsible for the apparent expansion of the wetter aspect facies of wet sclerophyll forest at the expense of drier facies.

If this is the case, decline in relative frequencies of the relative taxa at 6500 years B.P. may indicate reversion

to a vegetation distribution similar to that of today, under similar moisture regime.

At 3800 years B.P. there is a further significant decline in these moisture-indicating taxa. A minimum appears to have been passed through by about 1500 years ago, since when available moisture may have increased.

Generally, vegetation zones appear to have been relatively stable since the dramatic change c. 8700 years B.P. Eucalyptus PDR has declined slightly, however. Whether this is related to a decline in the altitude of the tree-line, to changes in pollen production associated with climatic change, or to errors in determination of sedimentation rate at this stage remains unknown.

Factors which the pollen trapping study could usefully investigate in relation to the interpretation of the pollen diagram include :

- i) The source of various pollen types. This has been assumed in the foregoing from taxonomic evidence.
- ii) Is differential pollen deposition a possible explanation of, for example, the high relative frequencies of small pollen grains in several taxa in the zone BL1?
- iii) Are observed pollen deposition rates in the cores, particularly that of Eucalyptus, consistent with the interpretation of vegetation history given above?

CHAPTER 4

ACTUOPALYNOLOGY

As outlined in the Introduction, the study involved sampling pollen and spores at various stages en route to their deposition in the lake sediments, by means of aerial pollen traps, snow cores, stream water samples and lake sediment traps. The locations of sampling sites in the alpine area are shown in figure 4.1; montane pollen trap sites are indicated on the vegetation map, figure 1.4.

Pollen trapping was begun in the 1969-1970 summer season, but because of deficiencies in trap construction and logistical difficulties, only a fragmentary seasonal record was obtained: results from this early period have been excluded. Estimates of mean pollen deposition rates, etc., are thus based on two year's sampling in the alpine and montane areas, although aerial pollen trapping was continued for slightly longer in the latter. Dates of sample collection are shown in figure 4.2. A two-month trap sample collection period was aimed at, but factors such as bad weather, road closure, availability of assistance, etc., commonly prevented this, as they also prevented collection of all samples on the same date.

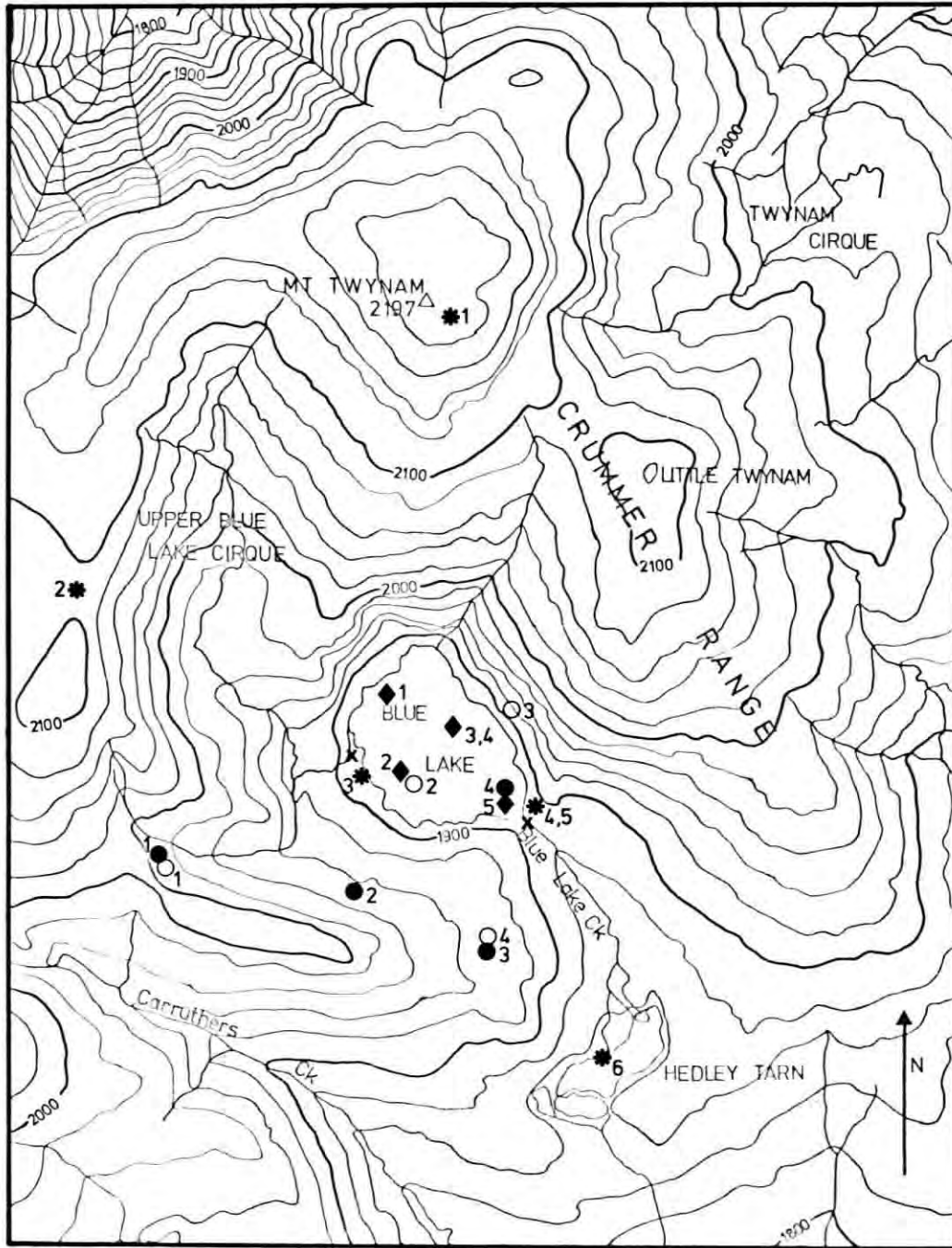
Trap samples were assigned a collection number (indicated at the head of figure 4.2) according to the period of collection. With the site code, this number identifies pollen trap collection periods and sites on the pollen diagrams of succeeding sections (and tables of Appendix D). Details of trap design, calibration, and sample processing are to be found in Chapter 2. Each sample type will now be considered in detail.

AERIAL POLLEN TRAPS

Siting

In selection of trap sites the following criteria were considered:

- i) Position relative to Blue Lake, in order that a good estimate be made of the pollen flux reaching the lake surface. Two sites were chosen on the lake shores, the Delta site being sheltered from the prevailing westerly winds, the Efflux site relatively exposed. At the latter site, two traps were set up, one roofed,



- | | | |
|--|---|---|
| <ul style="list-style-type: none"> ✱ AERIAL POLLEN TRAPS 1. Twynam summit (SUM) 2. Col (COL) 3. Delta (DEL) 4. Efflux (EFO) 5. Efflux roofed (EFR) 6. Hedley Tarn (HED) | <ul style="list-style-type: none"> ◆ LAKE SEDIMENT TRAPS 1. West (LWB) 2. South (LSB) 3. Central lower (LMB) 4. Central upper (LMT) 5. East (LEB) | <ul style="list-style-type: none"> ○ October, 1970 ● November, 1971 X STREAM SAMPLING SITE |
|--|---|---|
- 0 20m CONTOUR INTERVAL 1 km

FIG. 4.1 LOCATION OF MODERN POLLEN SAMPLING SITES, BLUE LAKE

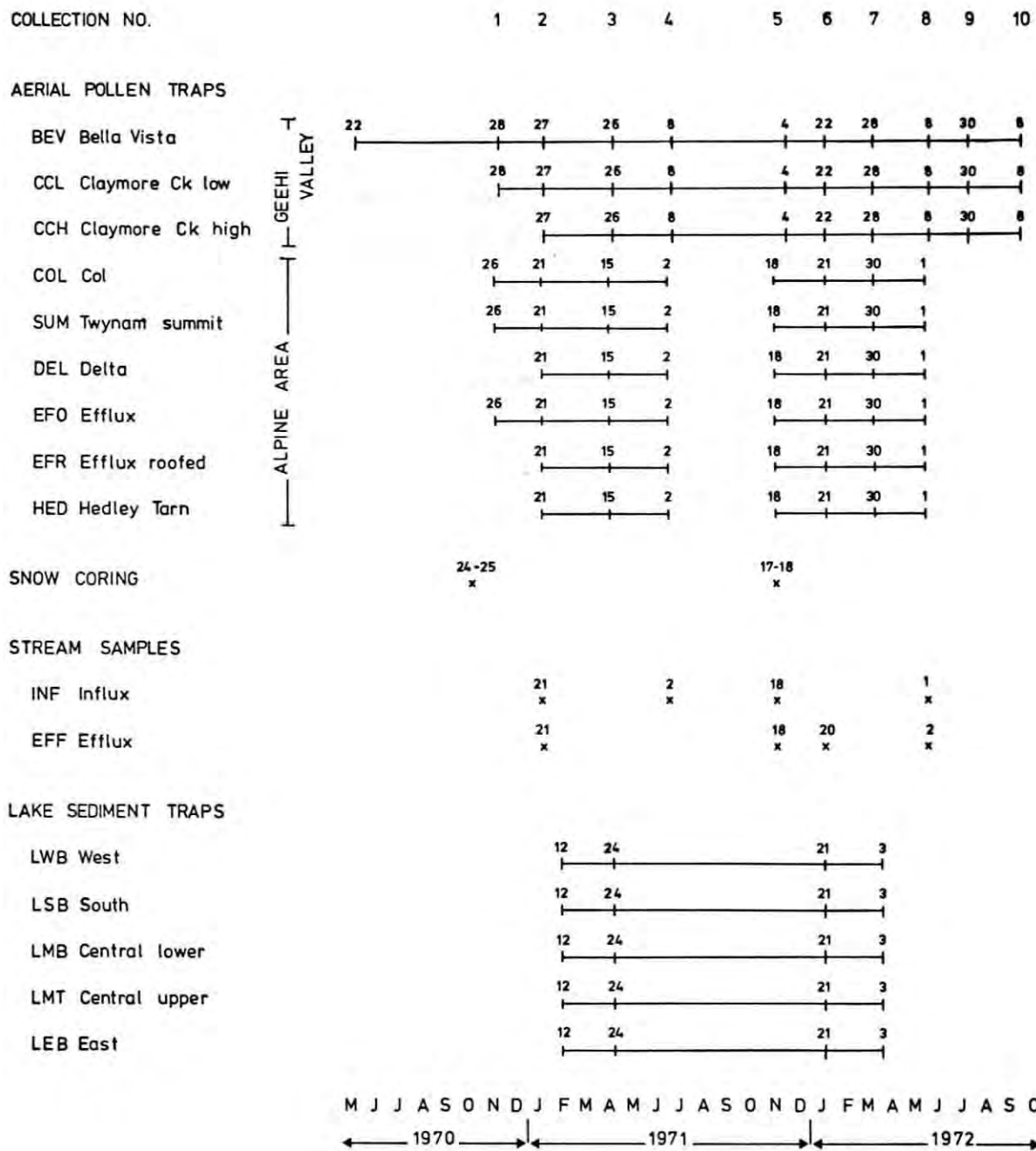


FIG. 4.2 MODERN POLLEN SAMPLE COLLECTION PERIODS & DATES

to investigate the nature of the rainout component of the pollen flux.

- ii) Position relative to vegetation zones, and thus also to major topographic features, so that variation in the pollen flux from forested to alpine areas might be investigated. Sites were distributed at different distances from the nearest treeline (disregarding subalpine woodland between Spencers Creek and the Snowy Mountains, which consists of scattered groups of trees):

Bella Vista	forest site c.5km from tree-line	
Claymore Creek	forest sites c.1.5 km	"
Col & Summit	alpine sites c.1.5 km	"
Delta & Efflux	alpine sites c.3 km	"
Hedley Tarn	alpine site c.4 km	"

- iii) Position relative to local topography and vegetation, in order that the general picture be not too distorted by purely local effects. To minimise overrepresentation of pollen of local plants, each trap in the alpine area was mounted on a post so that the orifice was in a horizontal plane 1 metre above ground level, and thus at least 80 cm above the local vegetation. The Geehi Valley traps, Bella Vista and Claymore Creek High, were sited in locally high open areas so as to catch the canopy component of the pollen flux, while the Claymore Creek Low trap was situated under the forest canopy, to sample the trunk space component.
- iv) Relative exposure. As mentioned above, the effect of different degrees of exposure to wind was investigated by siting traps according to exposure: Summit, Col, and Efflux traps being relatively exposed, Delta and Hedley Tarn traps sheltered. Simultaneous measurements of wind speed at the various alpine sites, using a fixed recorder and portable vane-type anemometer, yielded the following relative speeds for the prevailing southwesterly wind direction:

Summit	1.5
Col	1.2
Delta	0.7
Efflux	1.2
Hedley Tarn	0.8

- v) Ease of access, including freedom from heavy snow cover.

The Geehi Valley traps provided a continuous record of pollen deposition over the period of investigation. Because of the longer and rather different nature of their record, results are discussed separately from those of the alpine area traps, which follow.

Geehi Valley Traps (refer Appendix D, Table D.5)

- Bella Vista: The trap was 1m above ground in a clearing on a ridge top previously the site of a construction workers' settlement. The cleared area, about 4 hectares, was grassy around the pollen trap, but elsewhere covered by 2m high Acacia, Daviesia and Eucalyptus scrub regrowth. The surrounding shrub-floored forest is of the E. delegatensis association (see vegetation study site 12, Appendix C).
- Claymore Creek High: The trap was 10m above ground level on a road-bank, approximately at canopy level of surrounding E. viminalis forest (similar to that of the next site).
- Claymore Creek Low: The trap was 1m above ground level in E. viminalis forest with predominantly herbaceous understory, vegetation study site 15, approximately 20m from a disused forest track. This had been sown with Trifolium spp. as a soil conservation measure prior to commencement of trapping.
- Introduced plants were common along the road at both this and the previous site, but did not extend beyond the disturbed zone, approximately 1m on either side of the single-lane track.

Figure 4.3 illustrates the progression of total pollen deposition rates for the three trap sites. The pollen sum includes all pollen and fern spores identified as such: note that the PDR scale is logarithmic. Although there are differences in detail, peak PDR for all sites is reached in summer, minimum in winter.

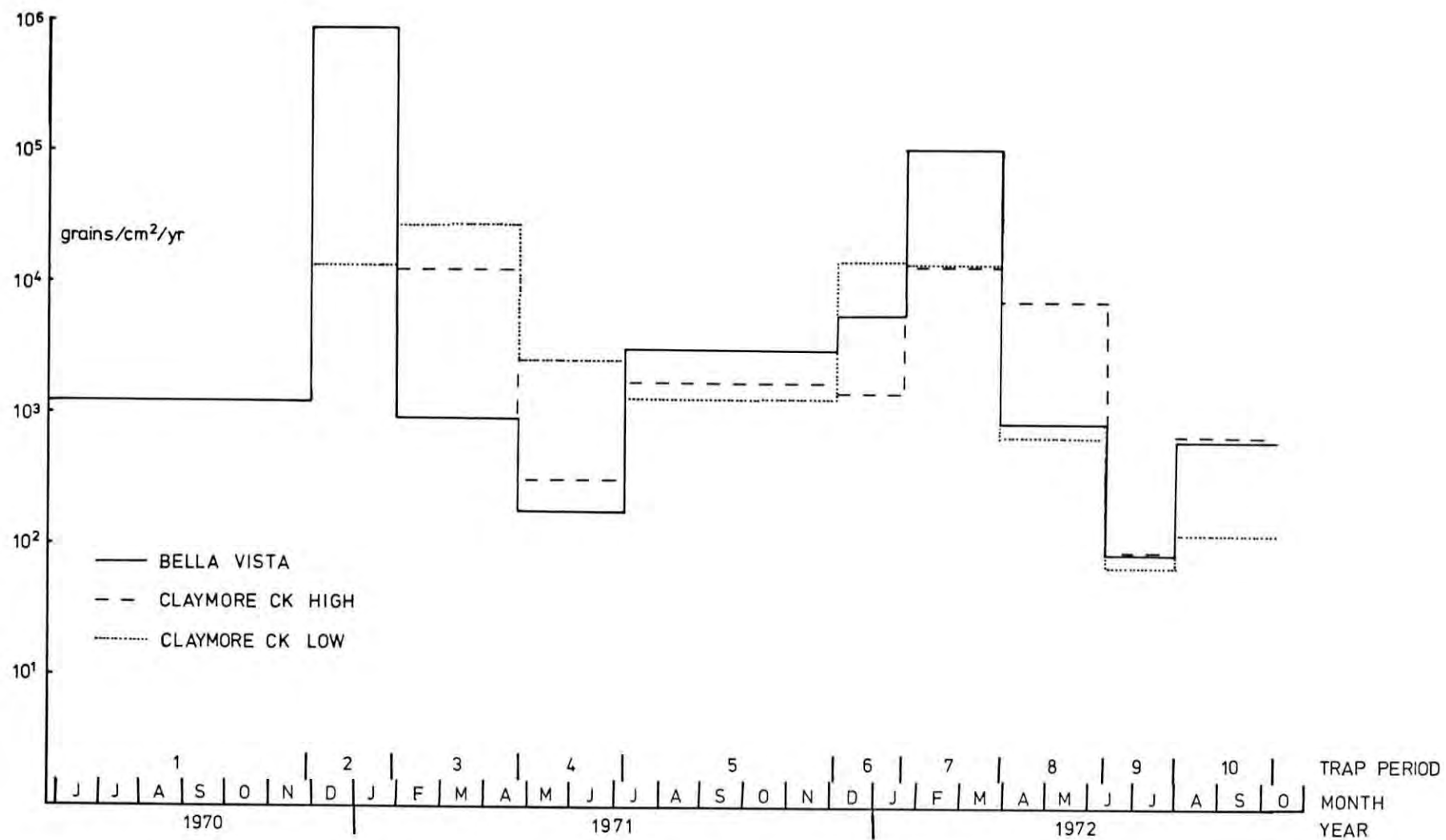


FIG. 4.3 POLLEN DEPOSITION RATE FOR GEEHI VALLEY TRAPS

Figure 4.4, the resolved RPF diagram shows the great variations in relative frequency between sites and collection periods, with sporadic dominance by Poaceae, Acacia, Indigofera comp., Daviesia sim., Eriostemon sim., Leptospermum sim., Parahebe comp., Asteraceae, and Pinus radiata. Eucalyptus is the only taxon represented in all samples, and shows peaks in trap periods 3, 5 and 8.

Calculation of PDR, as shown in the resolved diagram figure 4.5, immediately reveals the dangers of uncritical interpretation of an RPF diagram such as figure 4.4. Eucalyptus peak PDR is in periods 3 and 7, late summer to autumn, the peaks in periods 5 and 8 being reduced to little more than the general trend of rising PDR through spring and summer followed by a more rapid fall with the onset of winter. Again, however, there is considerable variation between sites, for Eucalyptus in several cases more than a factor of 10, for the one collection period. This is far greater than can be attributed to statistical error.

Important taxa are seen to be Poaceae, various Papilionaceae, Eucalyptus and Asteraceae; a wide variety of less important taxa occurs. Taxa not attributable to nearby disturbed areas or forest communities include: Typhaceae-Sparganiaceae, Casuarina, Banksia, Centrospermae, Myoporaceae, Callitris and Pinus radiata. In general, these are too sparse in occurrence for variation in PDR to be detected.

Examination of the diagram discloses several taxa which are more or less confined in occurrence to either the Bella Vista or the Claymore Creek samples. Thus Indigofera comp. and Hovea sim. at Bella Vista, and Lomatia, Parahebe comp., and Tieghemopanax at Claymore Creek. Pollen of Liguliflorae and Trifolium must be produced in the small disturbed area. Together with the great variation in PDR between sites shown by common taxa, this suggests that a great proportion of the pollen arriving at these sites is derived very locally - in the case of the Claymore Creek traps within the distance between them, a matter of only 300 m.

A complication is the occurrence of insect-borne pollen in the traps. The high counts of Papilionaceae, for example Daviesia sim. in Bella Vista period 2, are almost certainly due to this. Since Eucalyptus is mainly pollinated by blowflies (Pryor and Boden, 1962) its PDR may also be influenced by

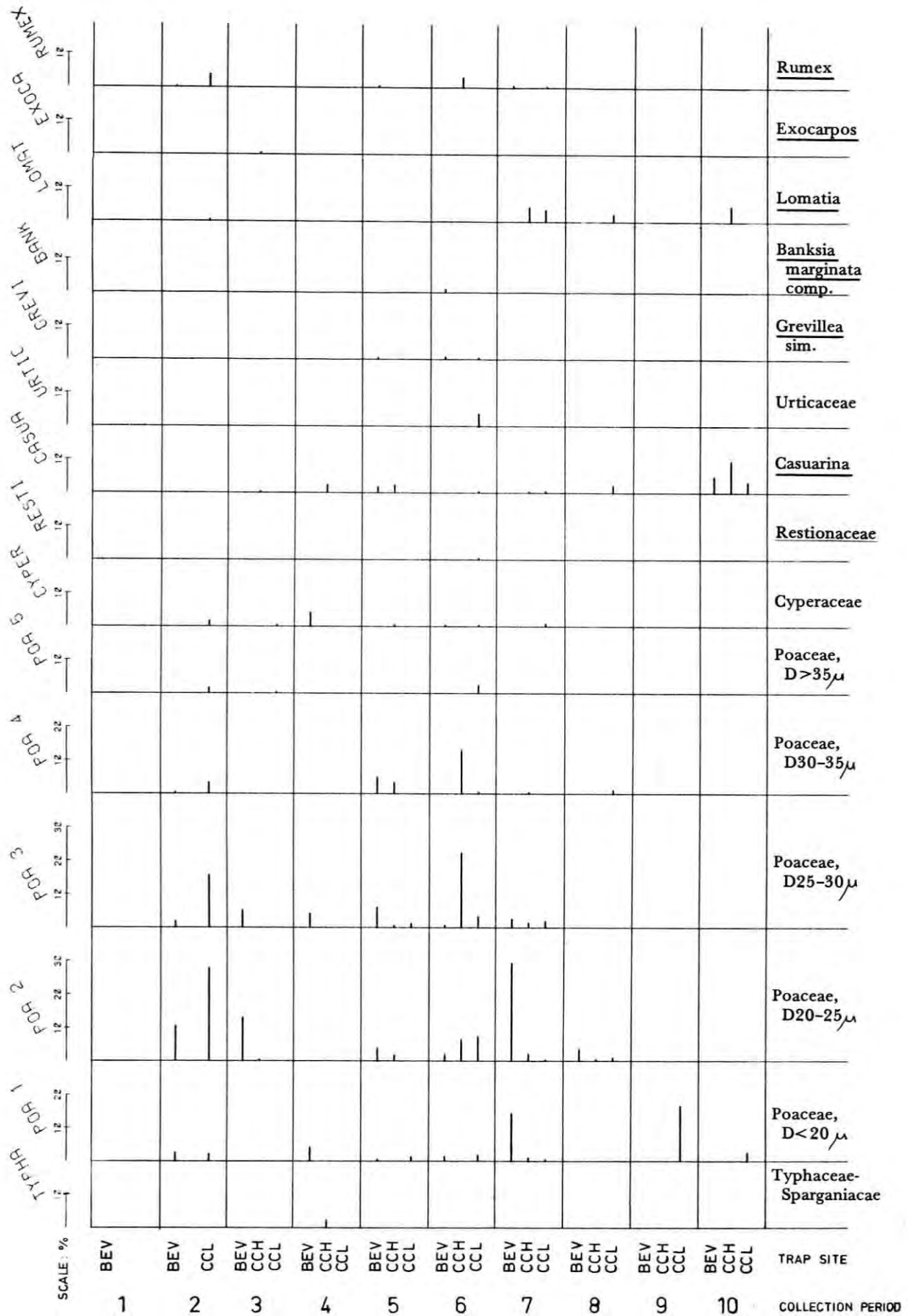


FIG. 4.4 GEEHI VALLEY TRAPS RPF DIAGRAM

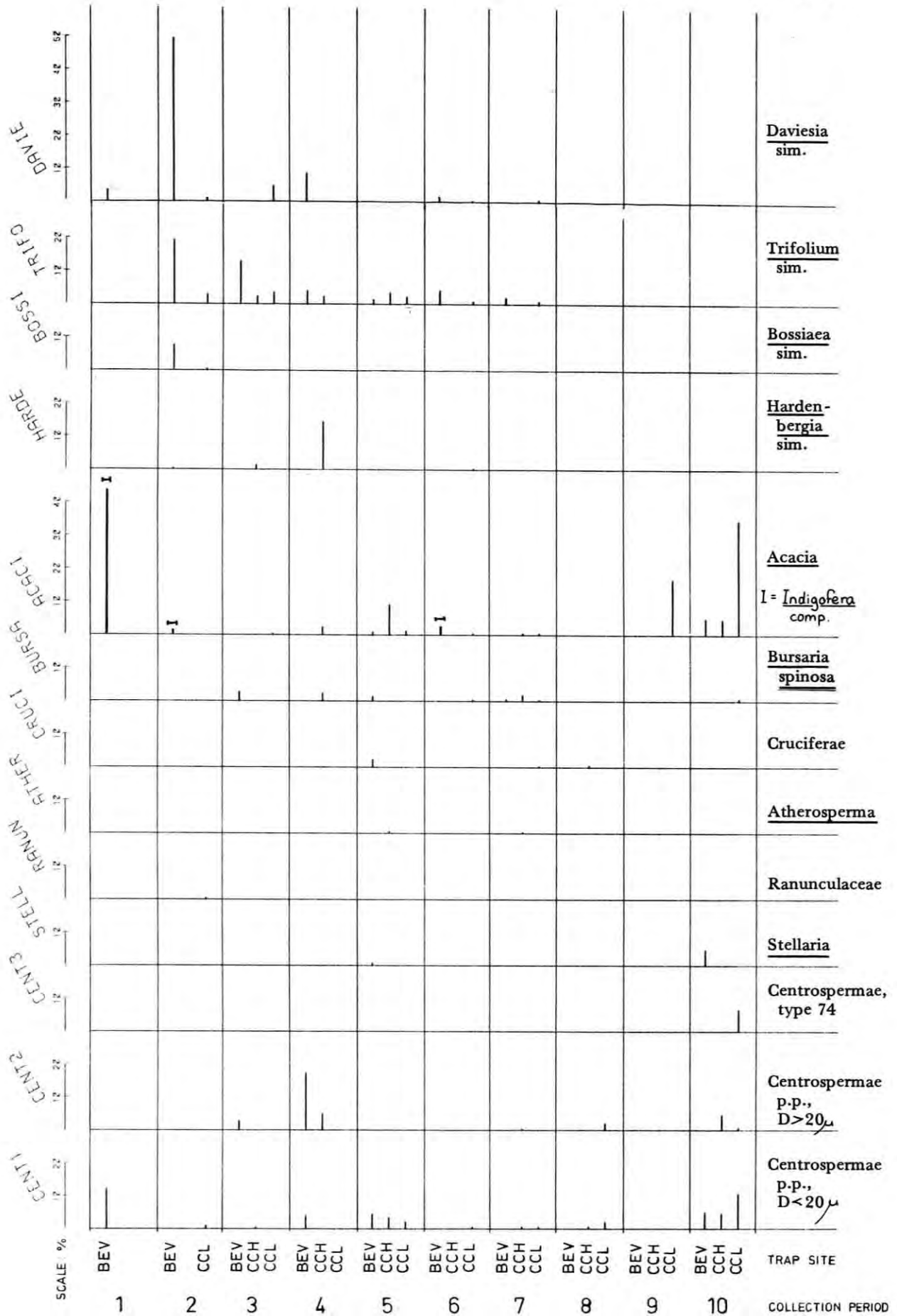


FIG. 4.4 GEEHI VALLEY TRAPS RPF DIAGRAM (continuation 1)

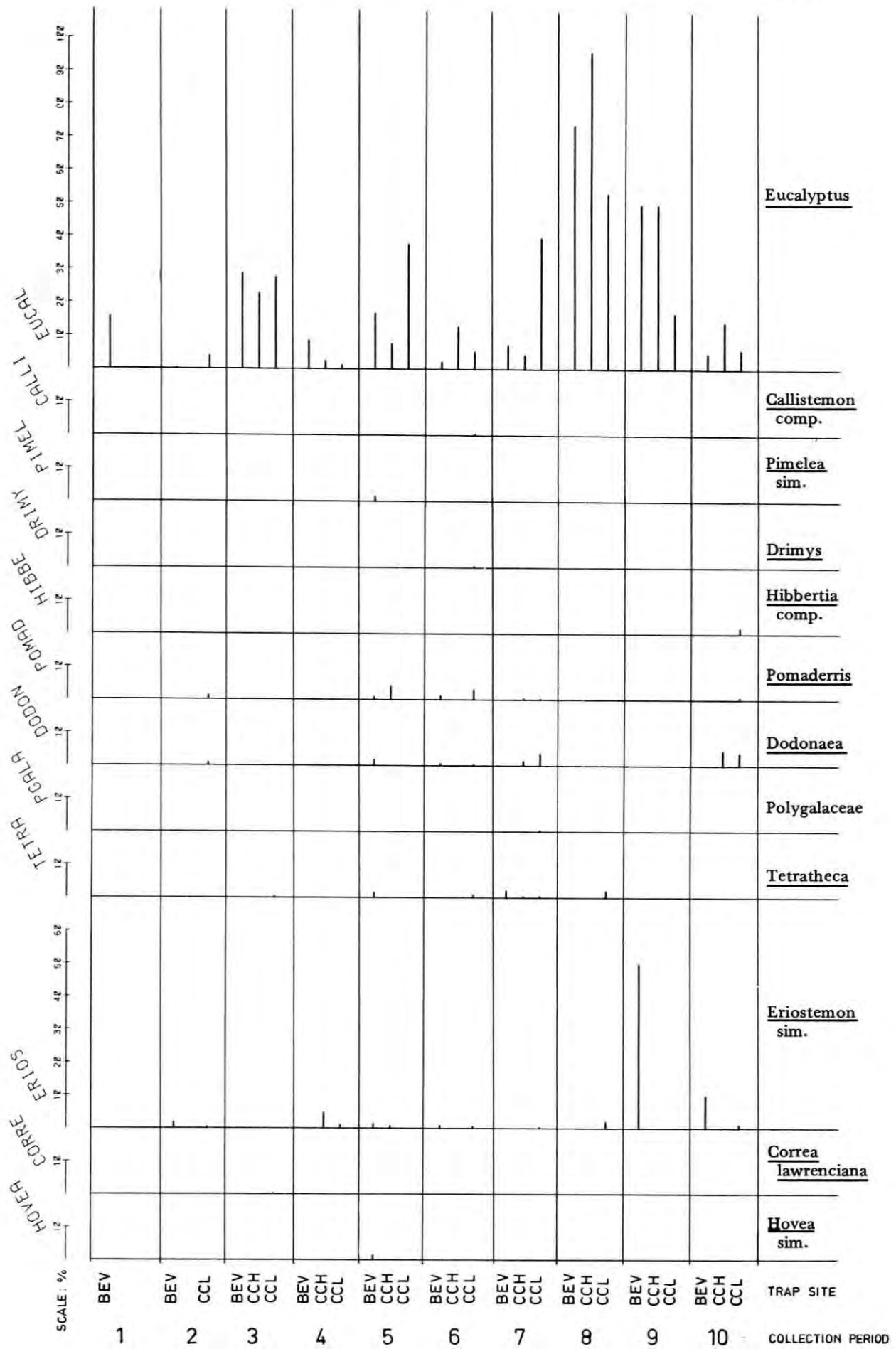


FIG. 4.4 GEEHI VALLEY TRAPS RPF DIAGRAM (continuation 2)

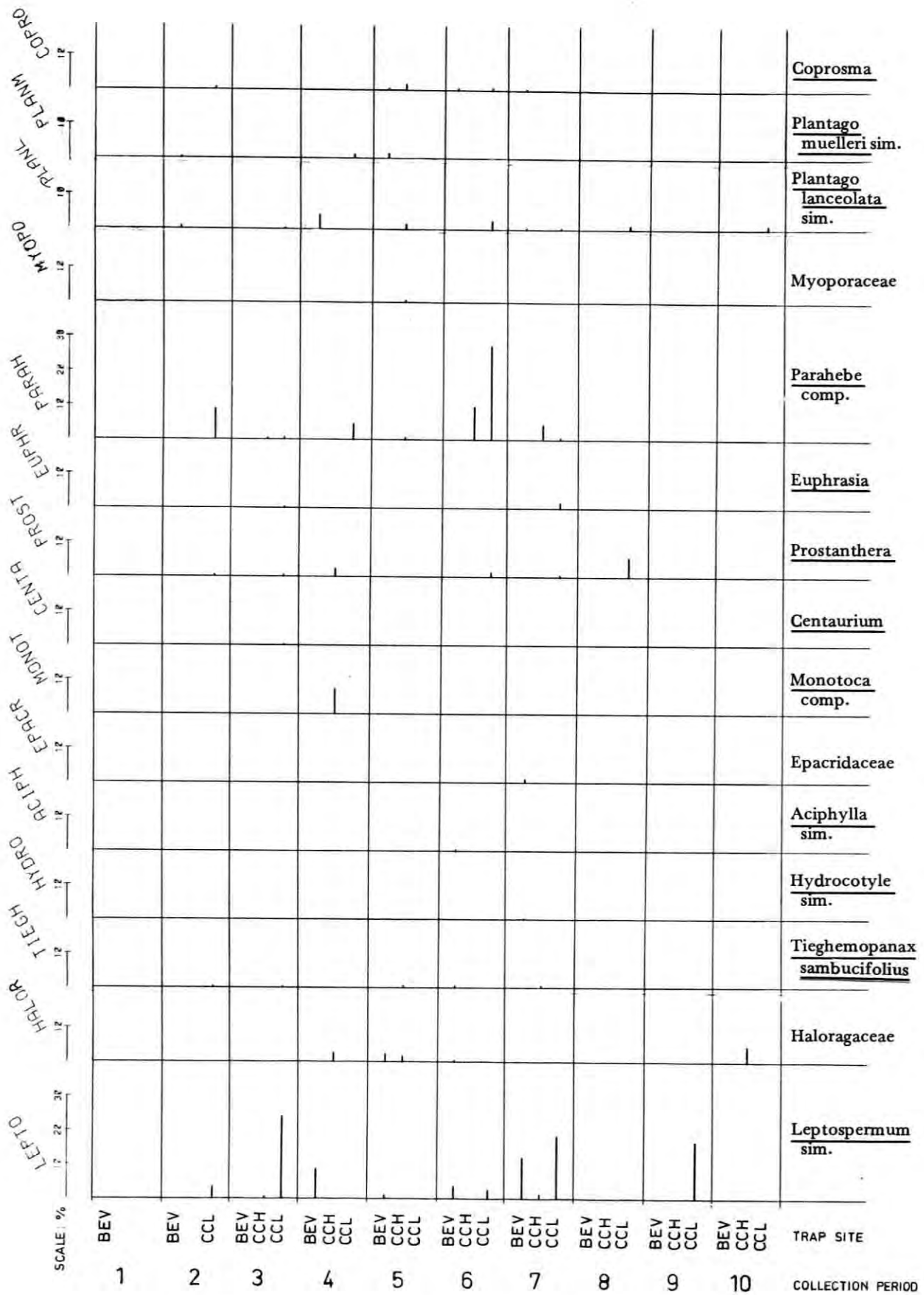


FIG. 4.4 GEEHI VALLEY TRAPS RPF DIAGRAM (continuation 3)

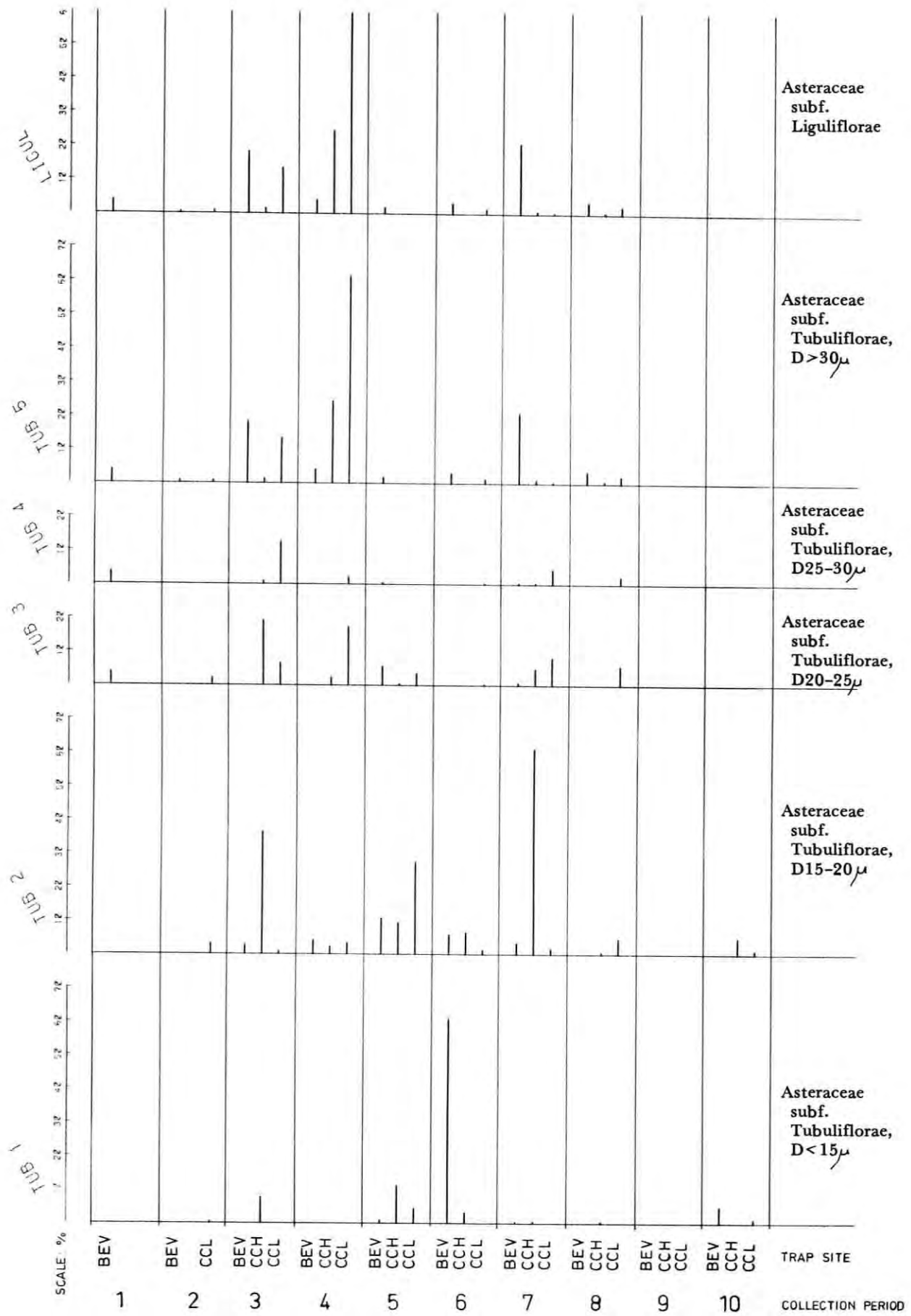


FIG. 4.4 GEEHI VALLEY TRAPS RPF DIAGRAM (continuation 4)

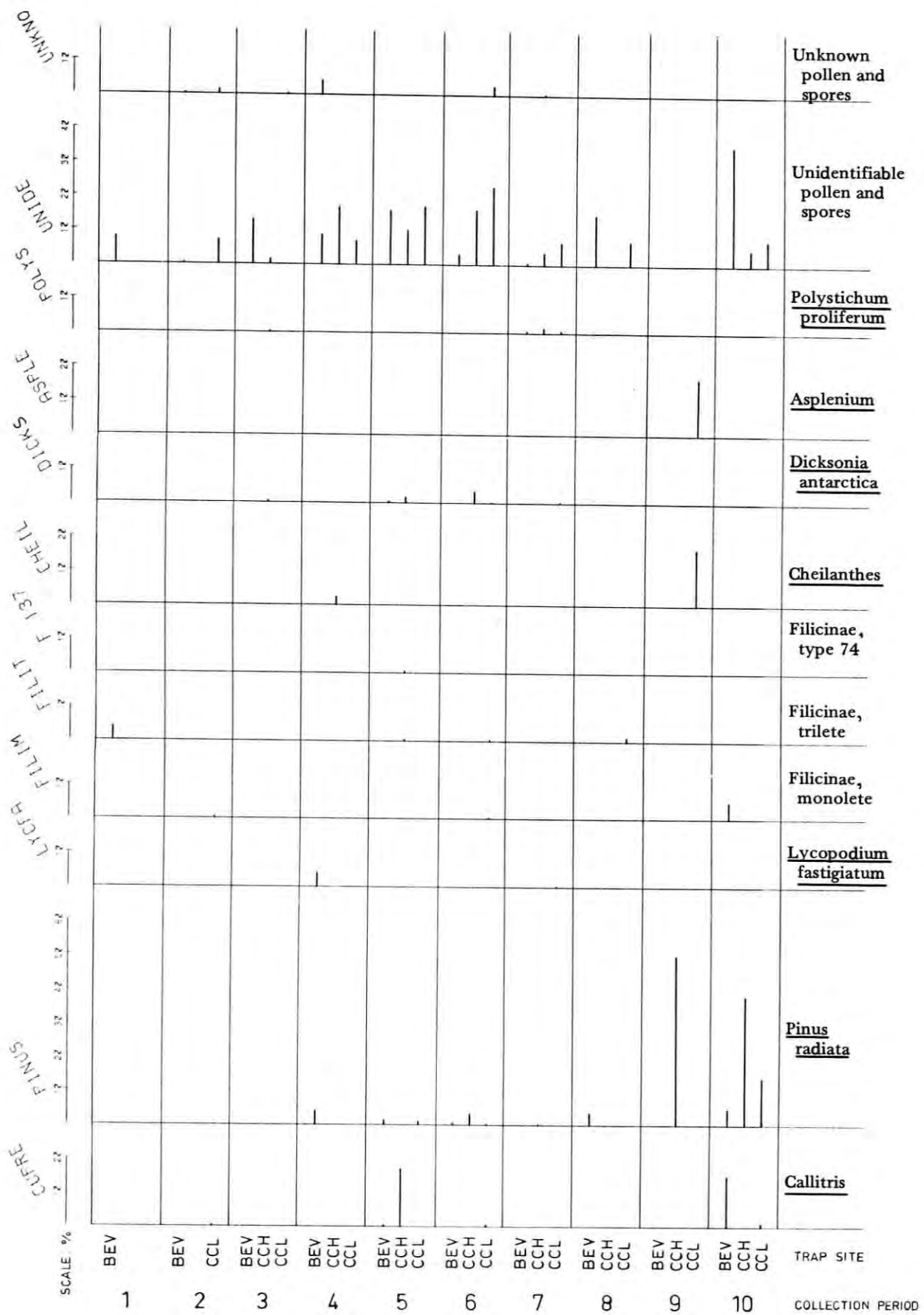


FIG. 4.4 GEEHI VALLEY TRAPS RPF DIAGRAM (continuation 5)

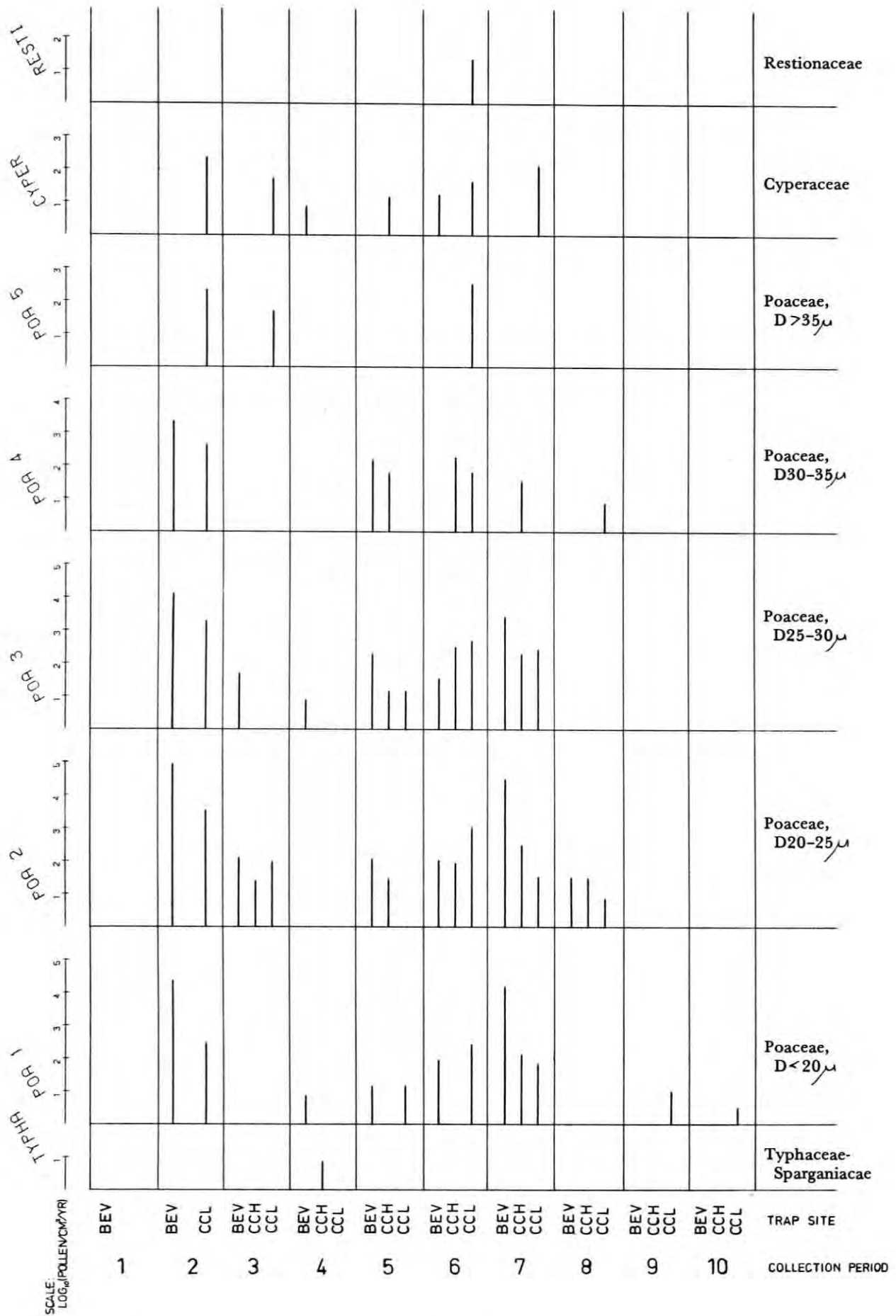


FIG. 4.5 GEEHI VALLEY TRAPS PDR DIAGRAM.

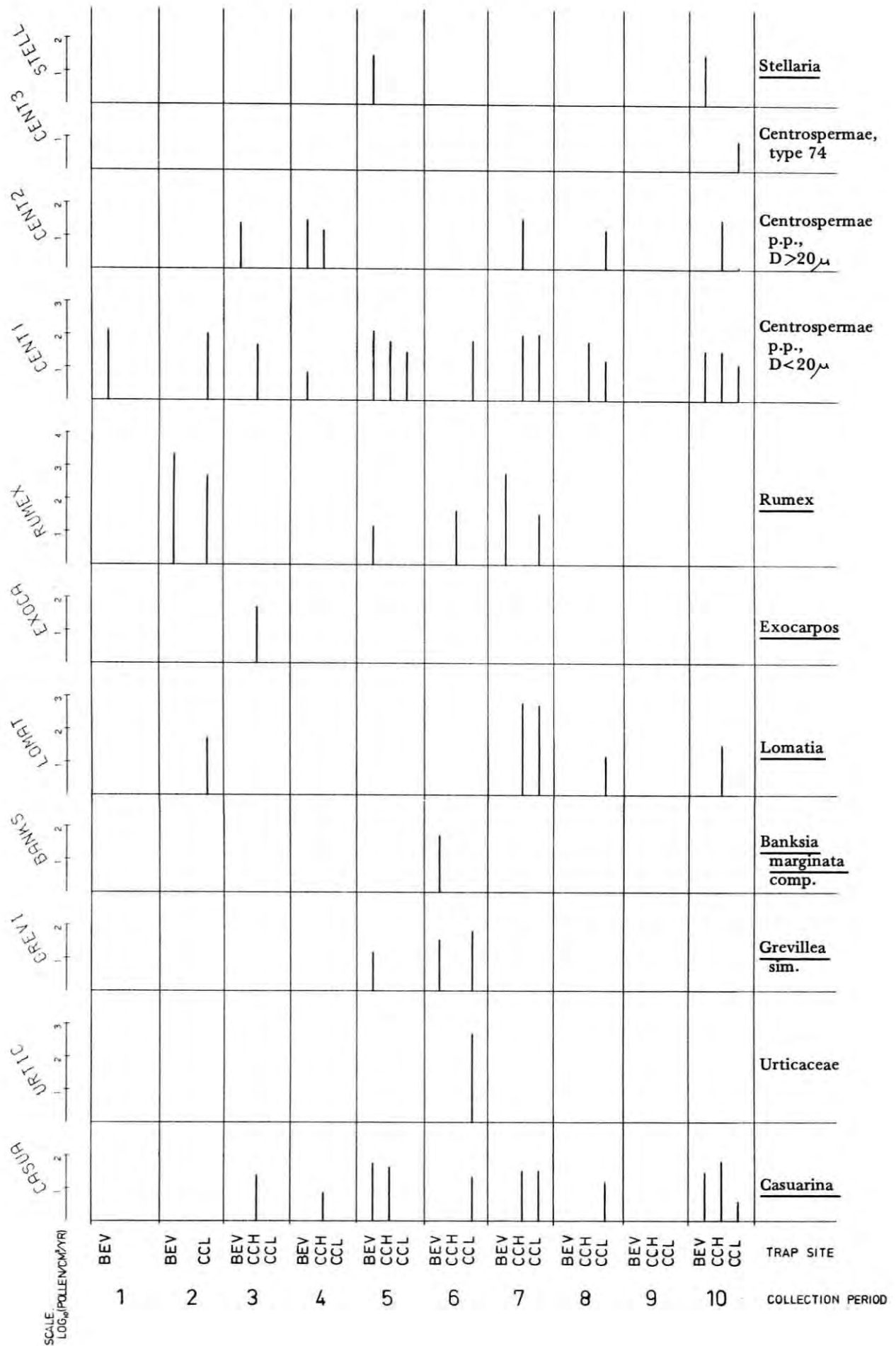


FIG. 4.5 continuation 1.

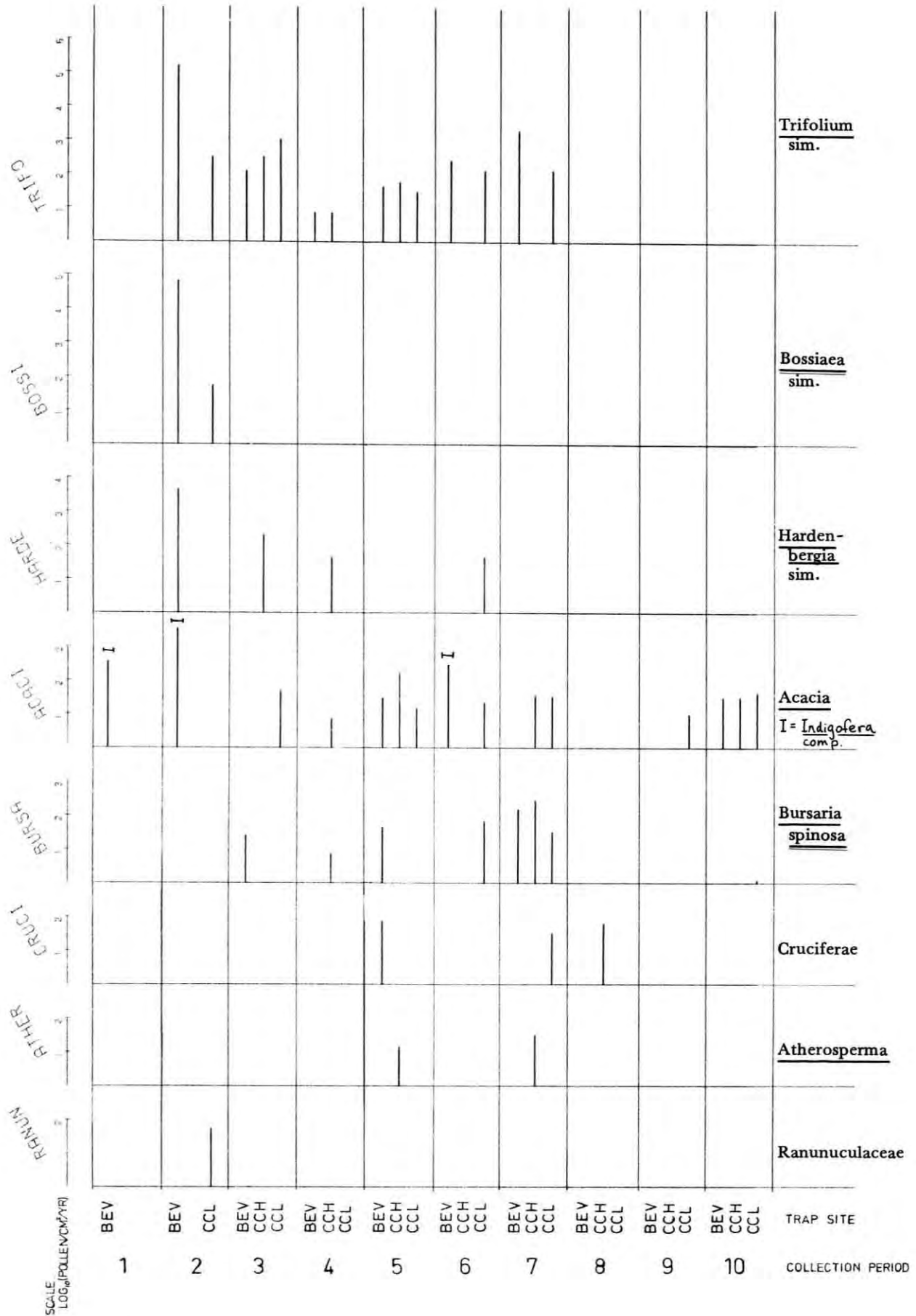


FIG. 4.5 continuation 2.

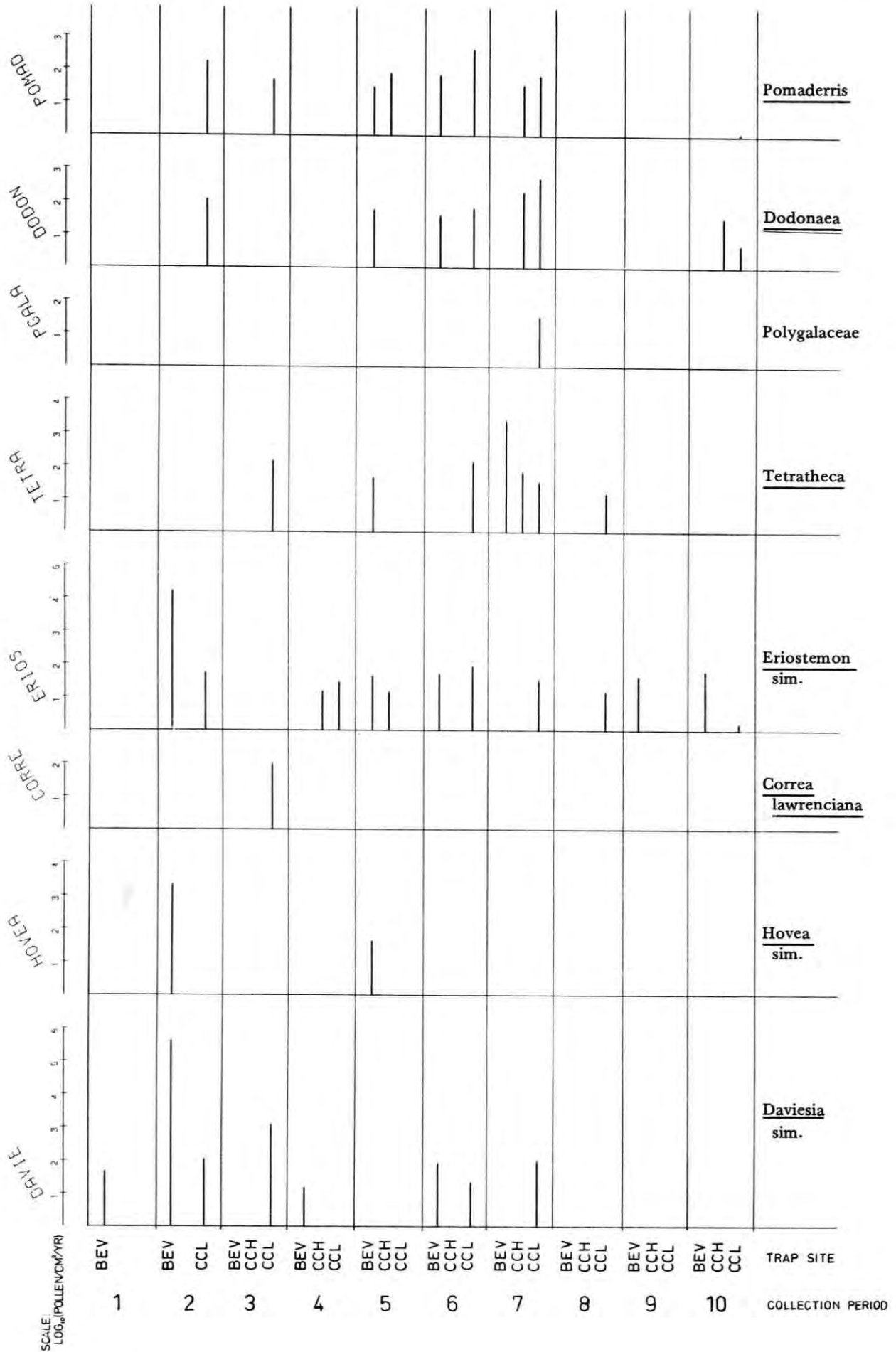


FIG. 4.5 continuation 3.

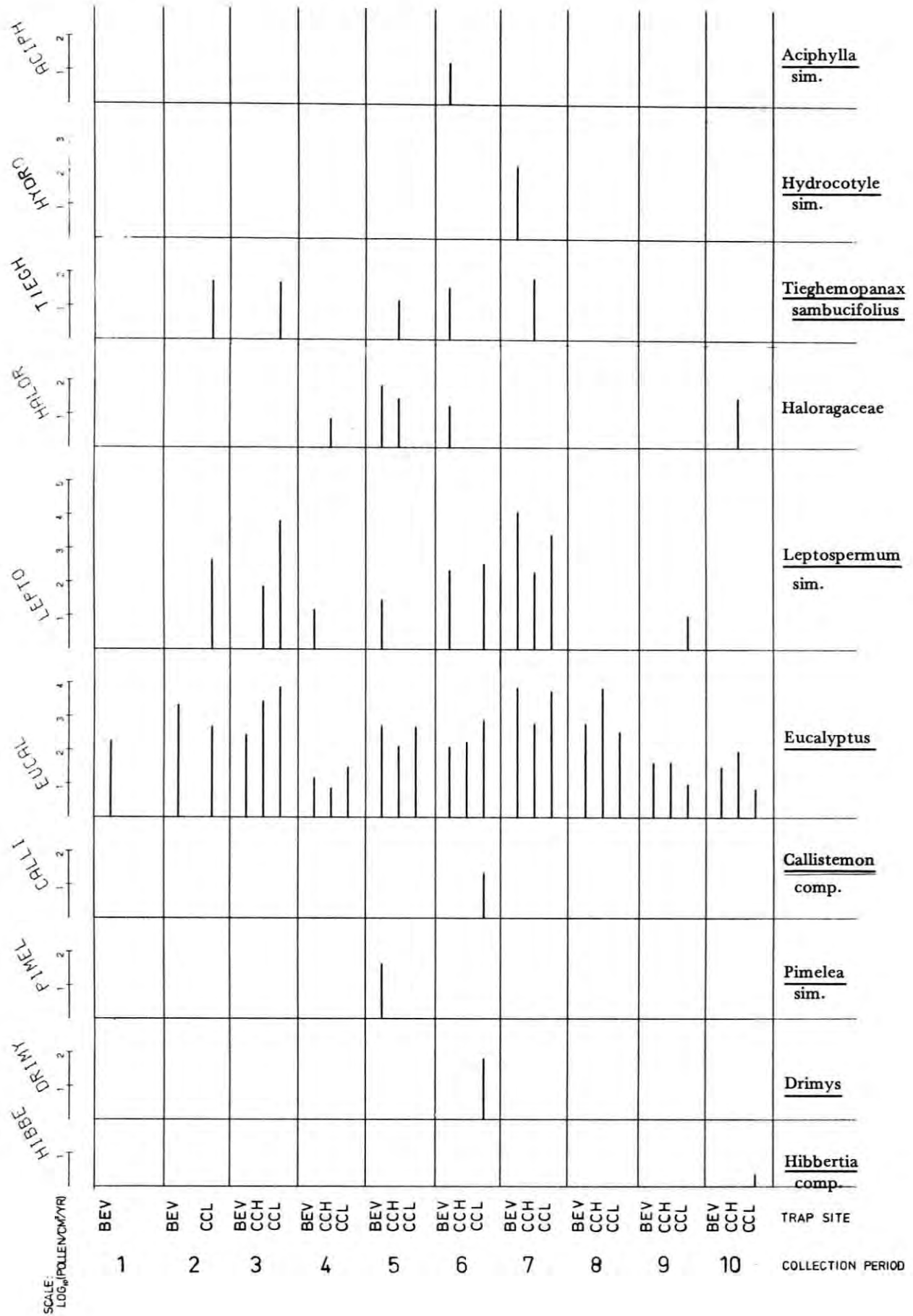


FIG. 4.5 continuation 4.

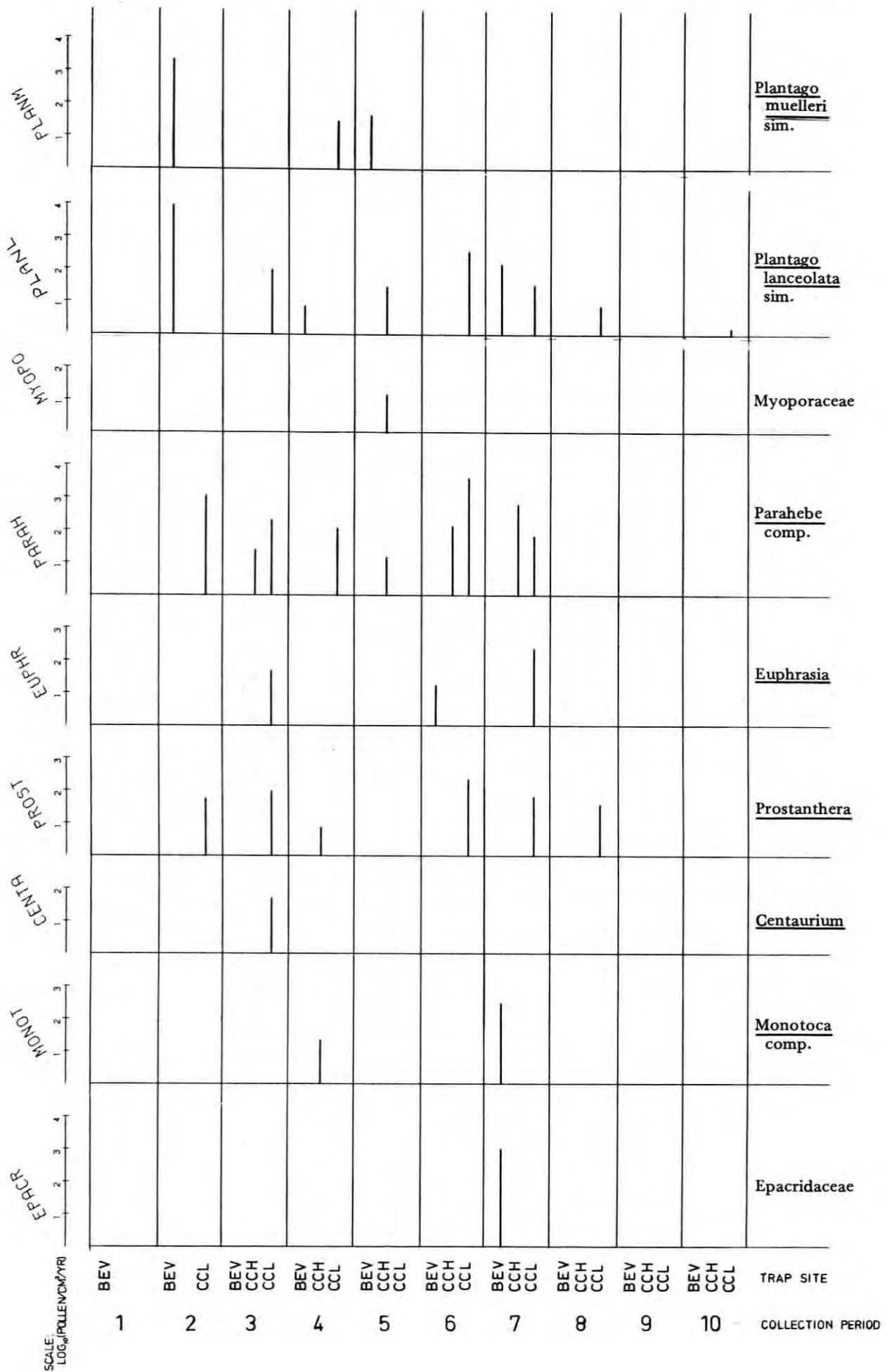


FIG. 4.5 continuation 5.

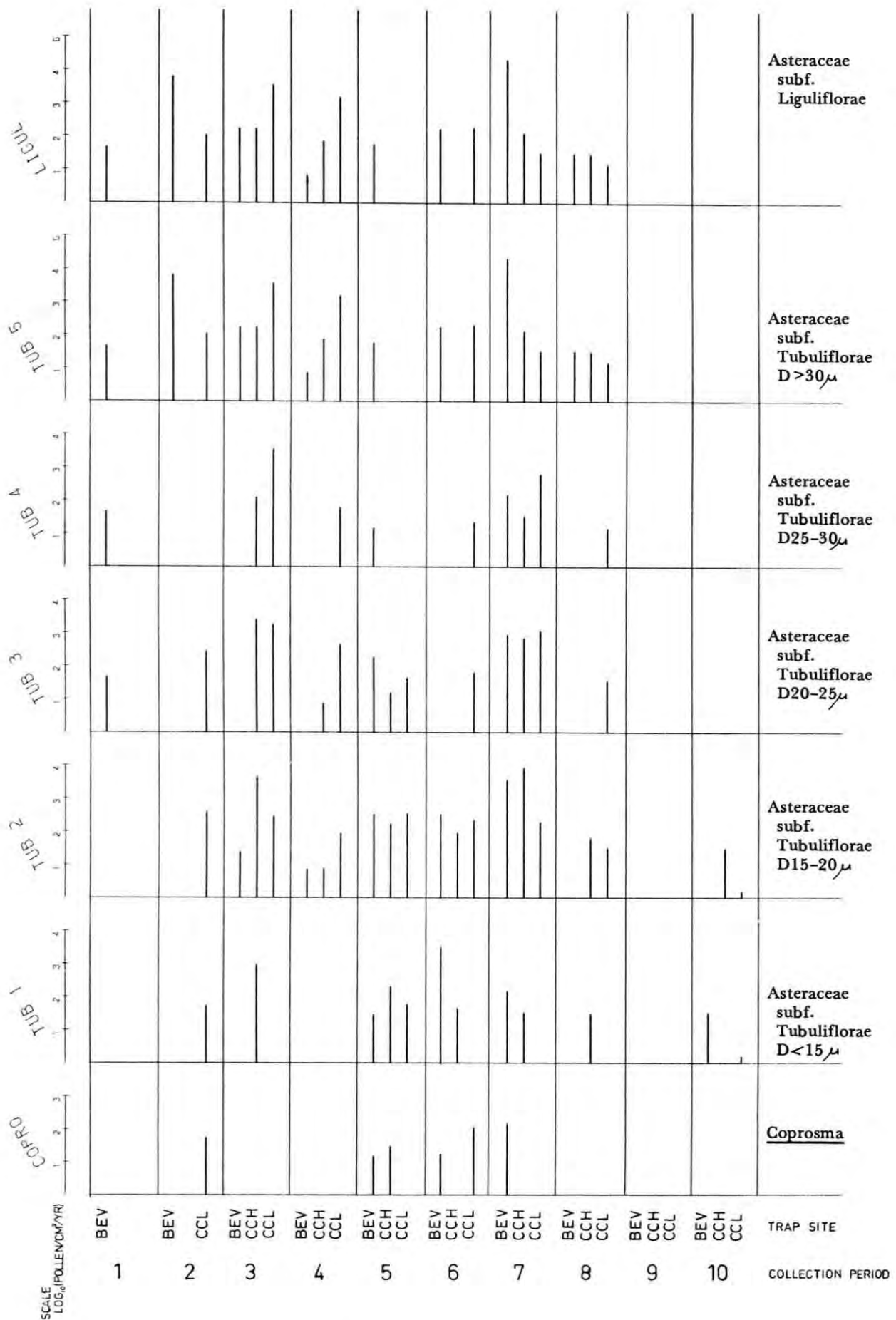


FIG. 4.5 continuation 6.

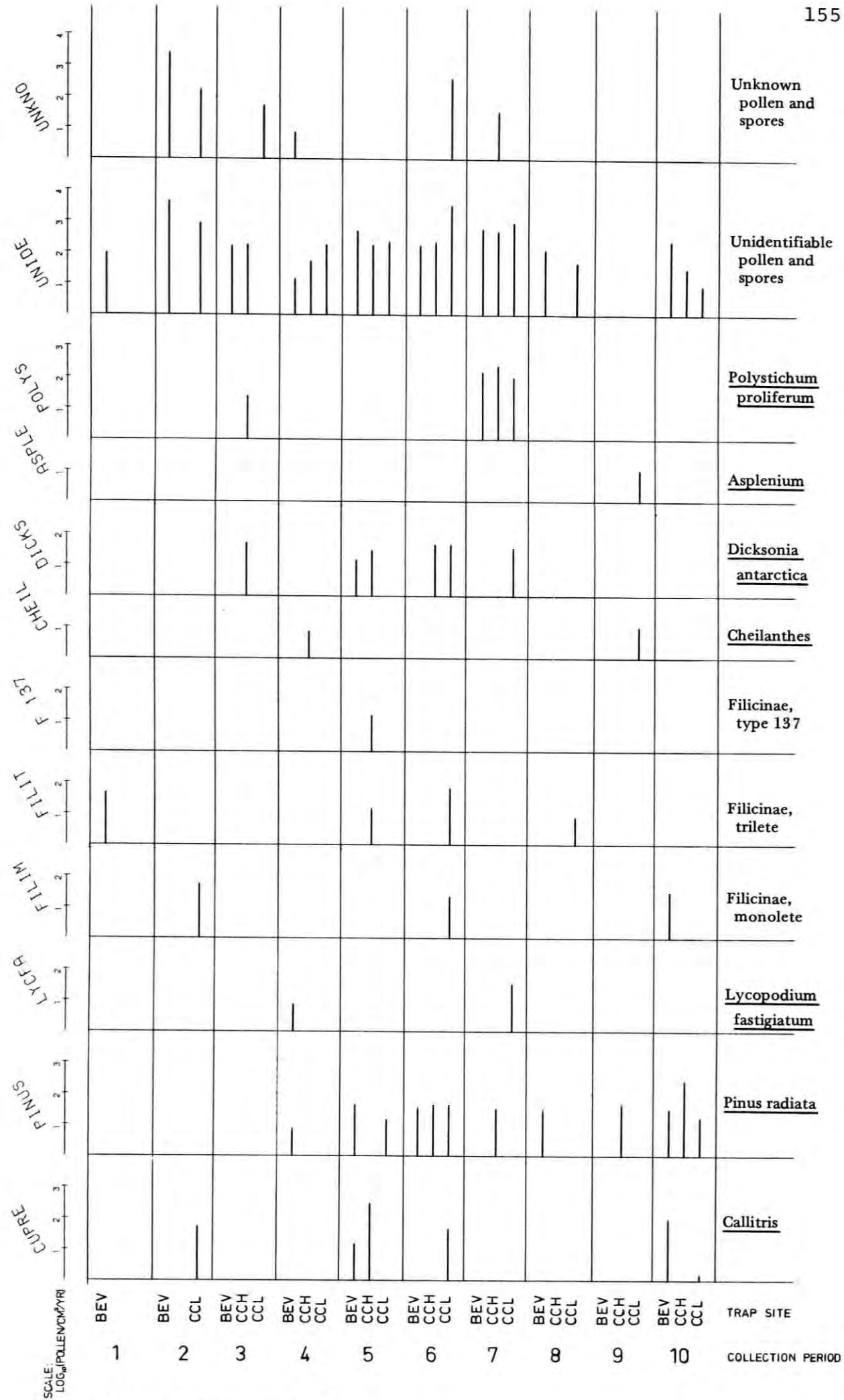


FIG. 4.5 continuation 7.

trapping of insects, which was observed to occur mainly in the summer months. It is not known which other taxa may be affected, but since the undoubtedly anemogamous Poaceae show considerable variation in PDR, the above remarks about local derivation stand, at least for sub-canopy taxa.

Systematic differences between the two Claymore Creek traps are hard to distinguish, partly because of the uncertainty introduced by the distance between them, but there does seem to be greater representation of sub-canopy taxa in the understory trap. Detailed statistical treatment would be necessary to establish this.

Alpine Area Traps (refer Appendix D, Table D.6)

Situation of the various traps with respect to plant communities can be seen in figure 1.5. Attempts were made to commence trapping at the time of lake ice break-up, simultaneously with snow sampling. This was achieved in the second season, but in the first season snow sampling was carried out a month before ice break-up. Three traps were installed at this time, the other three at the end of the first collection period. In each season, permanent lake-ice was formed during the last trap-period.

Figure 4.6 shows the progression of total pollen deposition rates for the alpine trap sites during each season. Except for Col period 2 and Delta period 7, total PDR declines through the season at each site. The latter exception is due to the presence of a large amount of insect-contributed Wahlenbergia pollen in the trap, but the low count for Col period 2 remains unexplained. Possibly it is due to processing error.

Examination of the resolved RPF diagram, figure 4.7, reveals that there is less inter-site variation than between the Geehi Valley traps. Main taxa are again Poaceae, Eucalyptus and Asteraceae, but Rumex and Centrospermae are also important, whereas Papilionaceae are not so. A few taxa have lower RPF during the first season, for example Poaceae, Cyperaceae and Callitris, resulting in higher RPF for other taxa.

In the resolved PDR diagram, figure 4.8, it can be seen that practically all taxa have lower PDR in the first season: apparently Poaceae, Cyperaceae and Callitris were depressed more than most. Sporadic high counts in the following taxa are probably due to insects caught in the traps: Grevillea

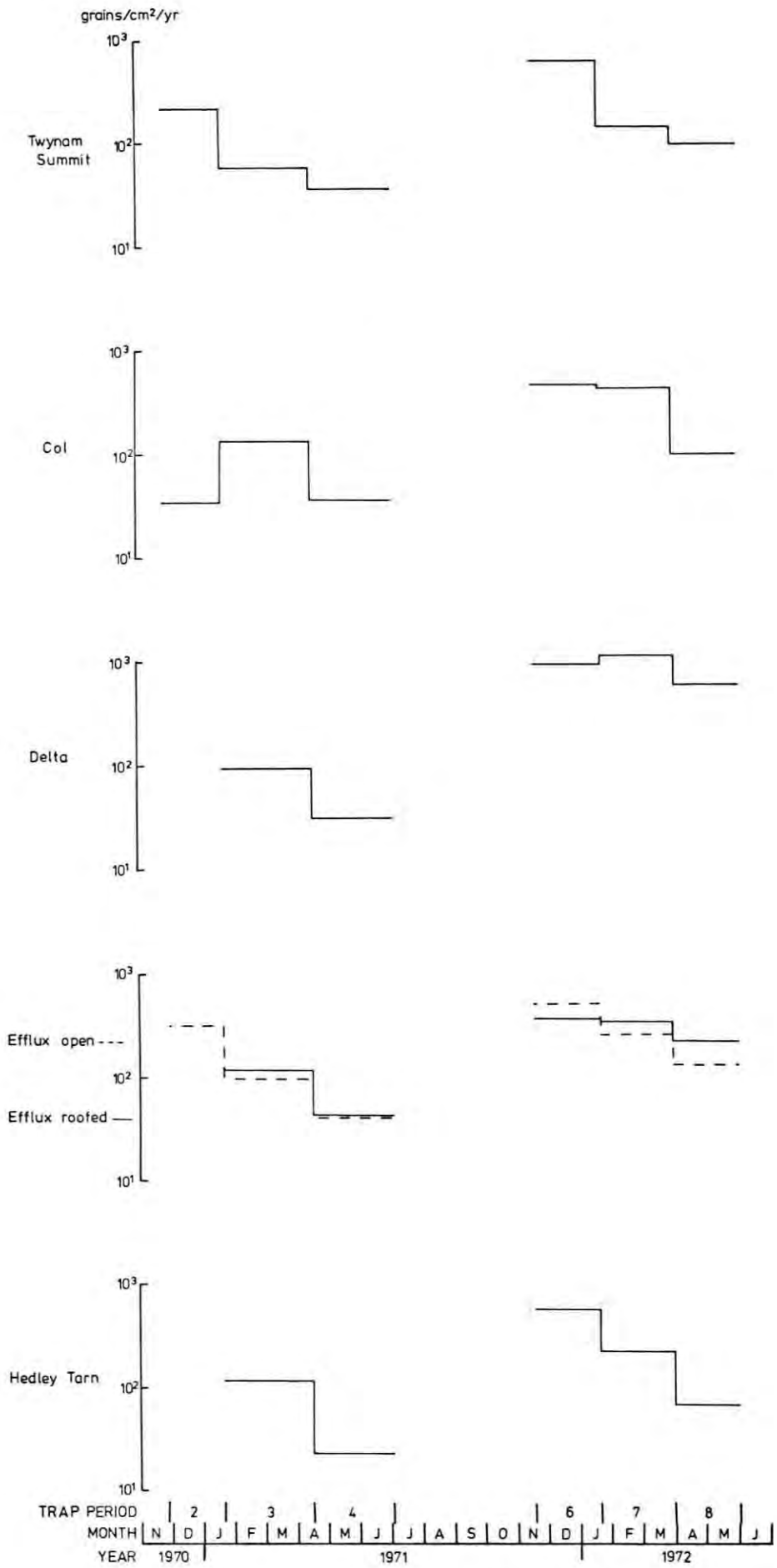


FIG. 4.6 POLLEN DEPOSITION RATE FOR ALPINE AREA TRAPS

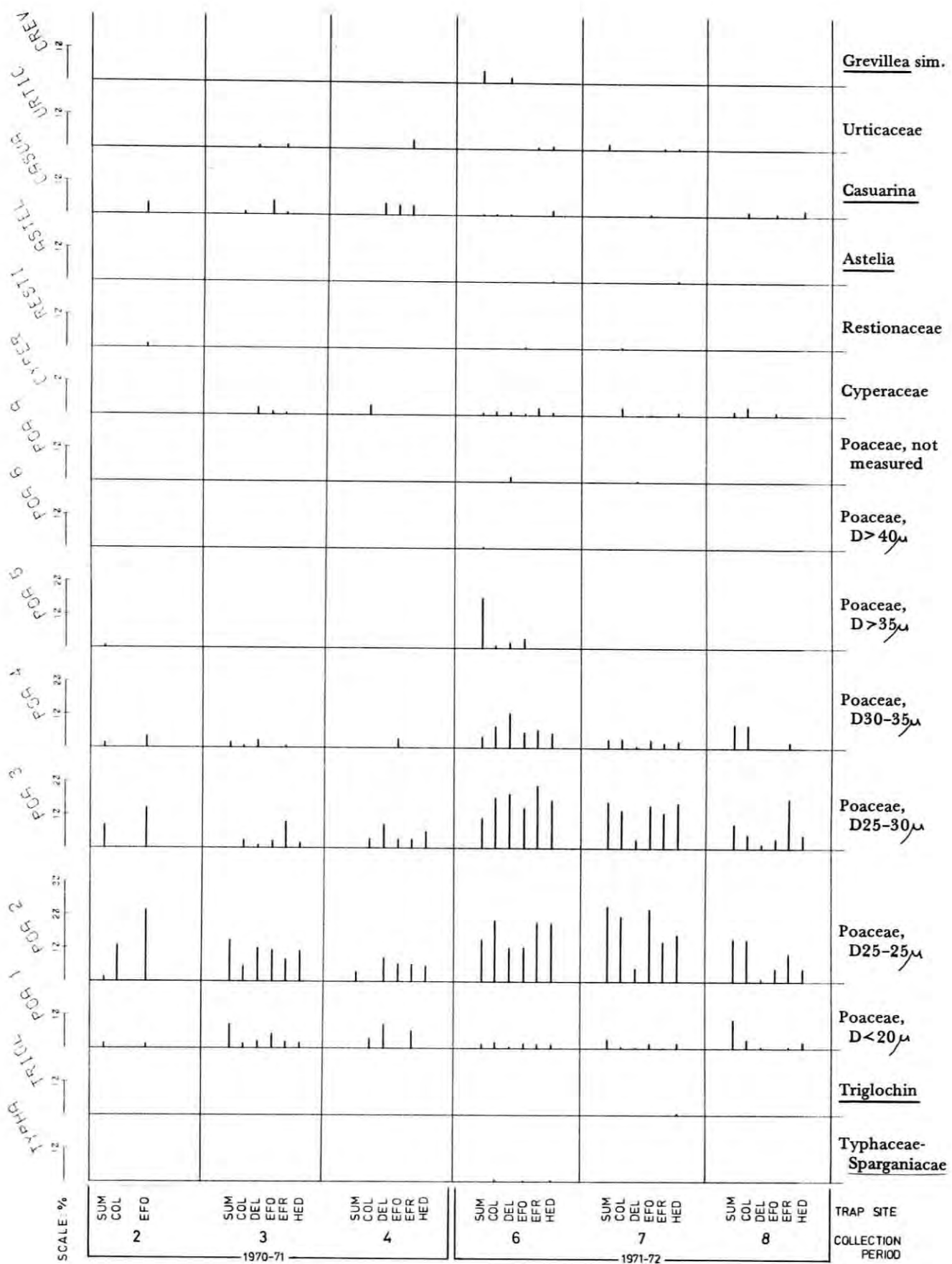


FIG. 4.7 ALPINE POLLEN TRAPS RPF DIAGRAM

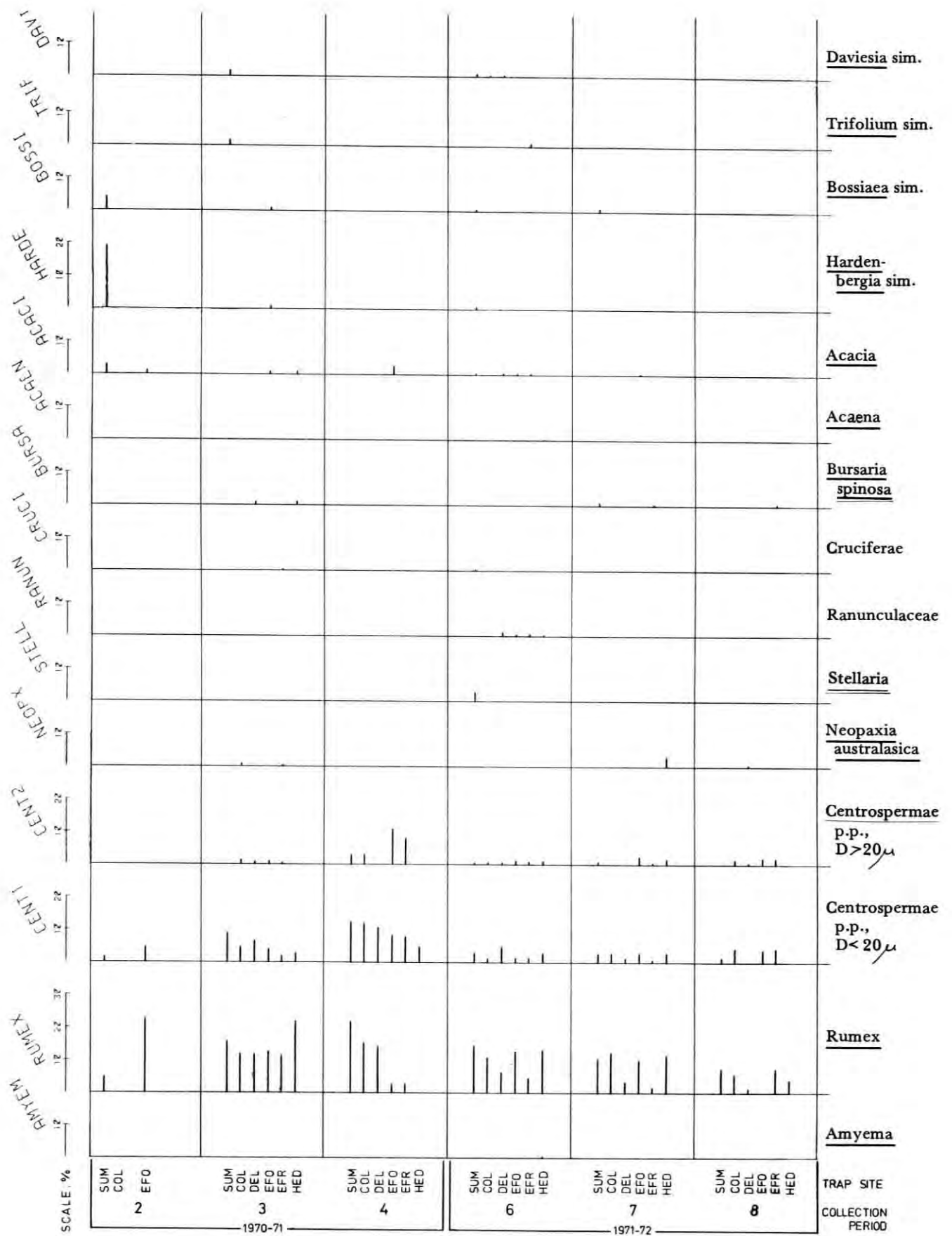


FIG. 4.7 ALPINE POLLEN TRAPS RPF DIAGRAM (continuation 1)

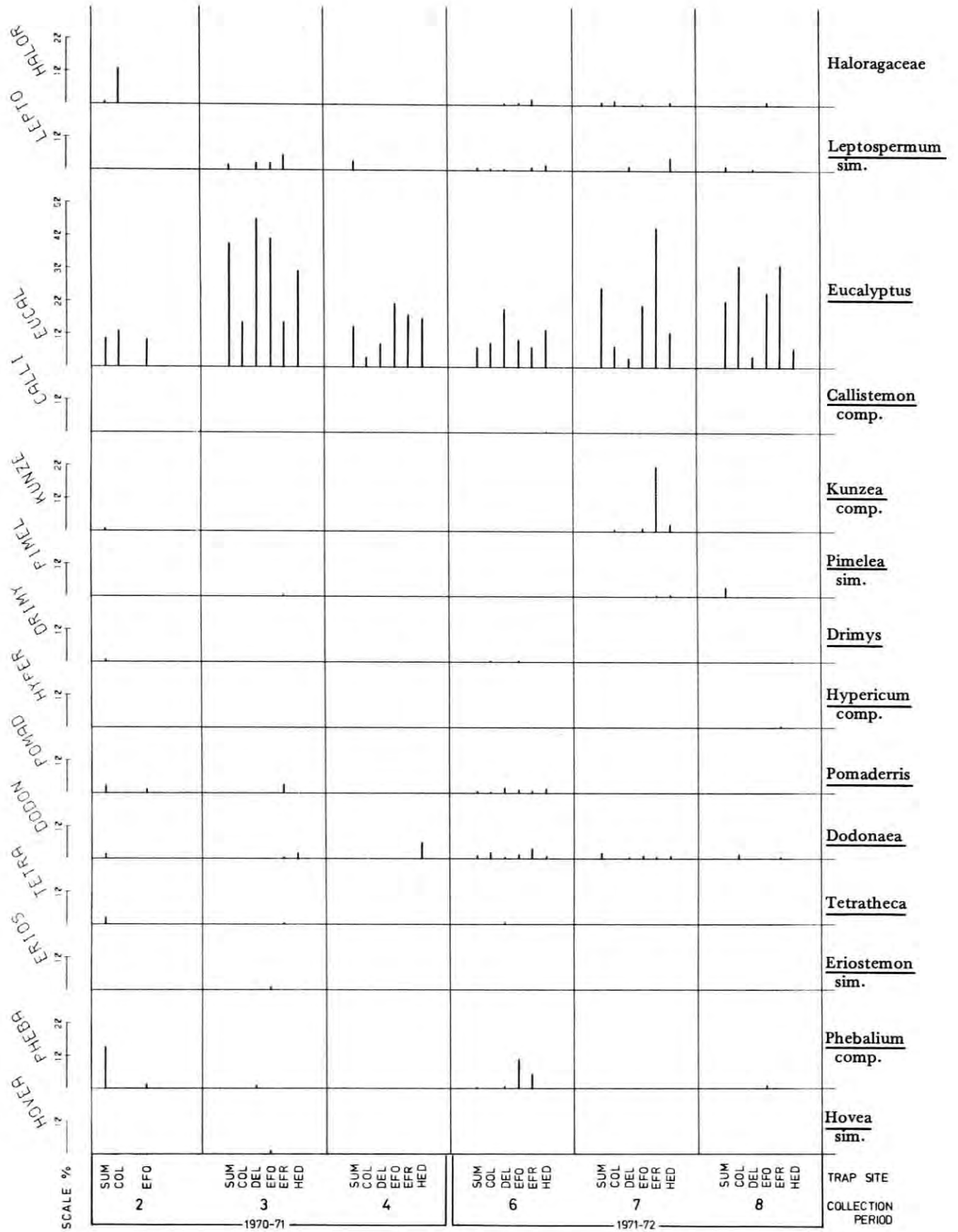


FIG. 4.7 ALPINE POLLEN TRAPS RPF DIAGRAM (continuation 2)

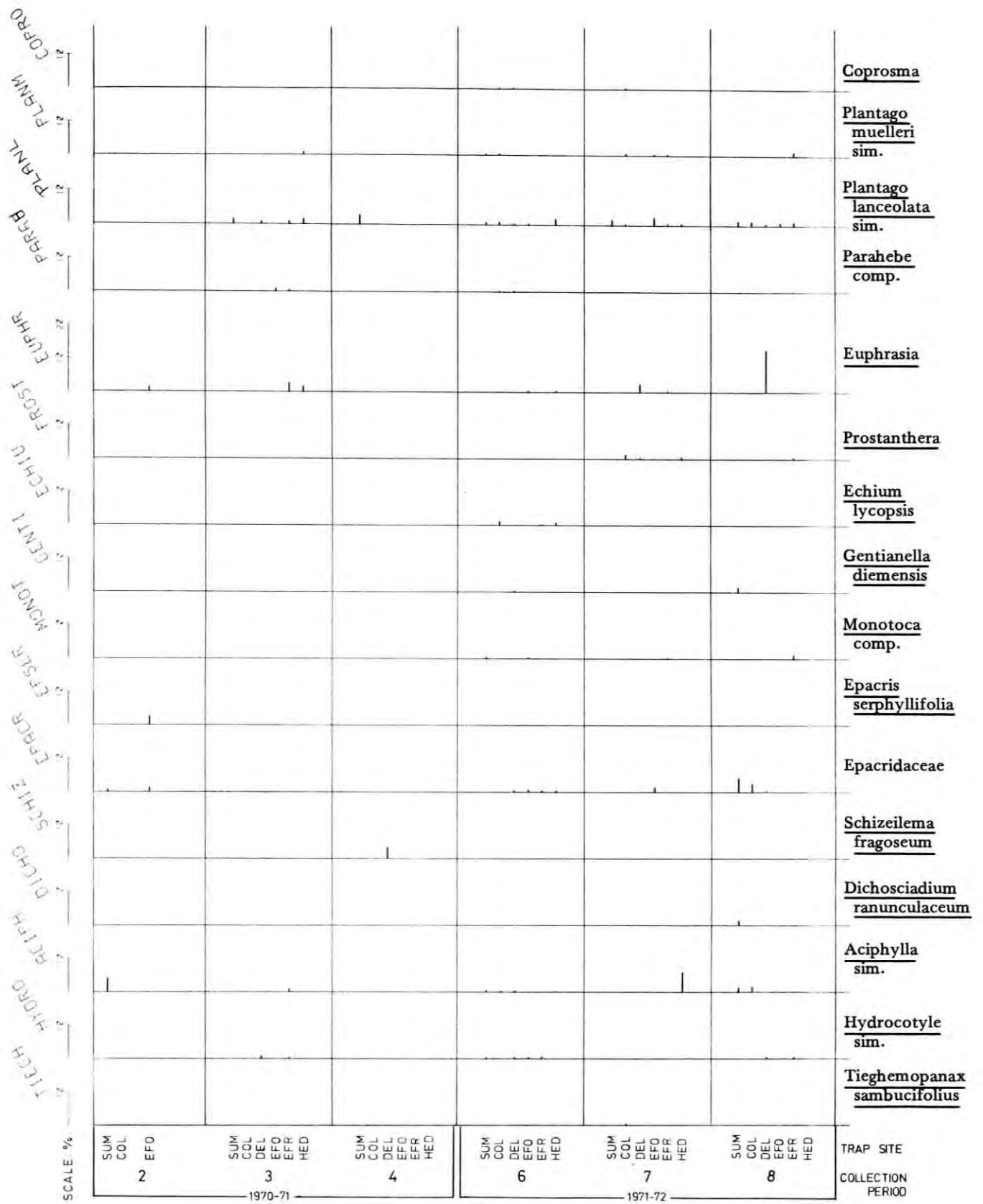


FIG. 4.7 ALPINE POLLEN TRAPS RPF DIAGRAM (continuation 3)

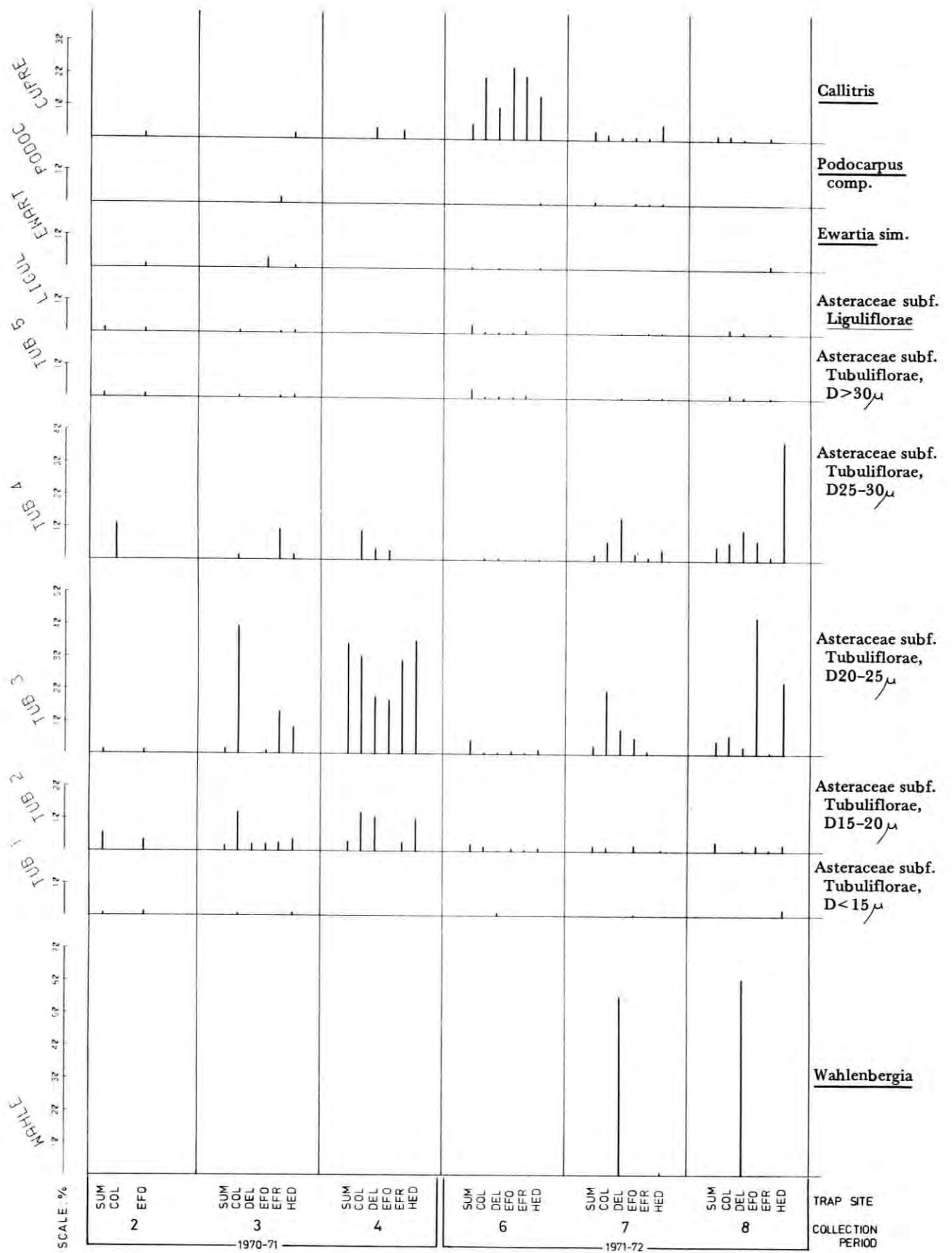


FIG. 4.7 ALPINE POLLEN TRAPS RPF DIAGRAM (continuation 4)

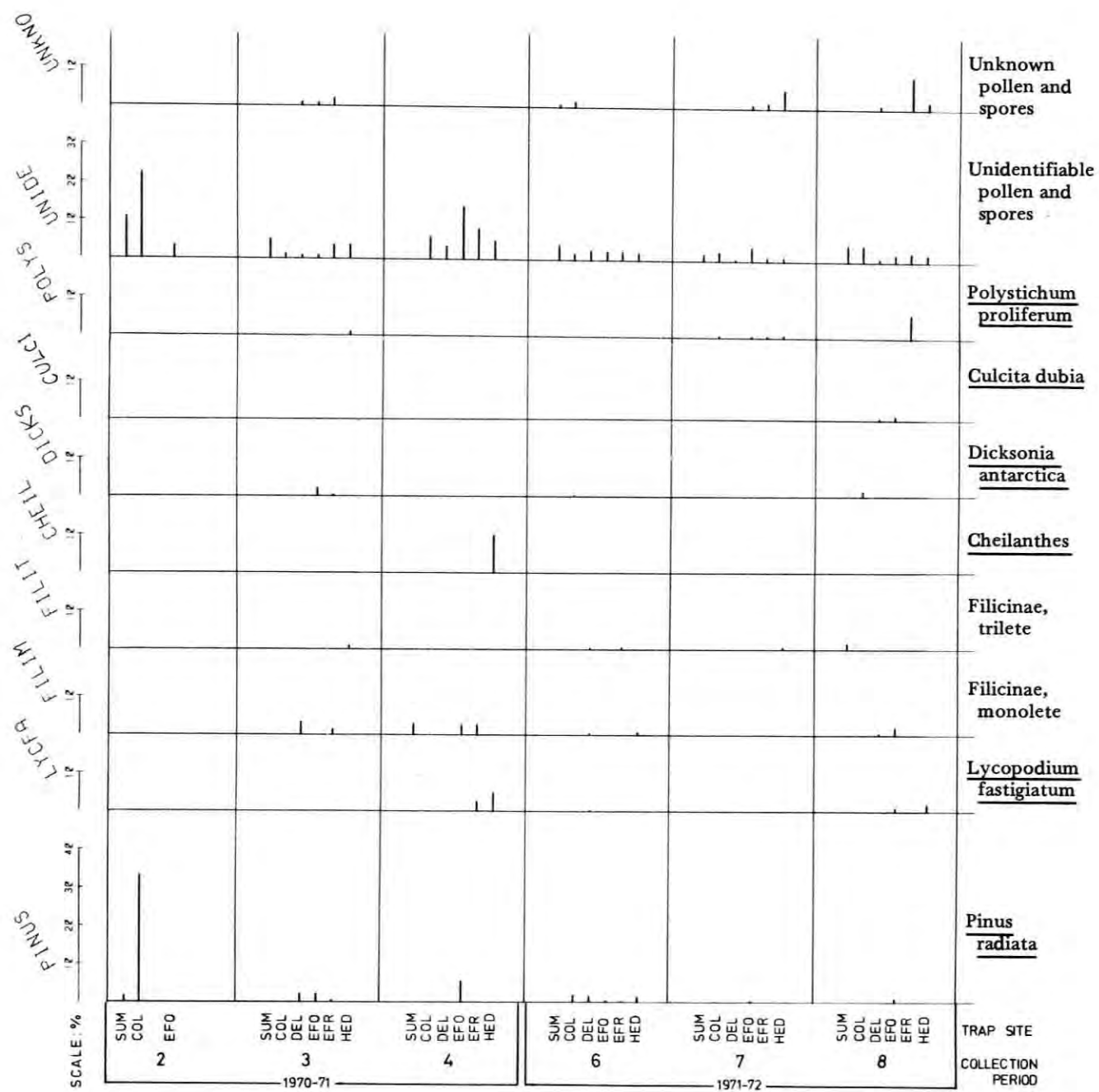


FIG. 4.7 ALPINE POLLEN TRAPS RPF DIAGRAM (continuation 5)

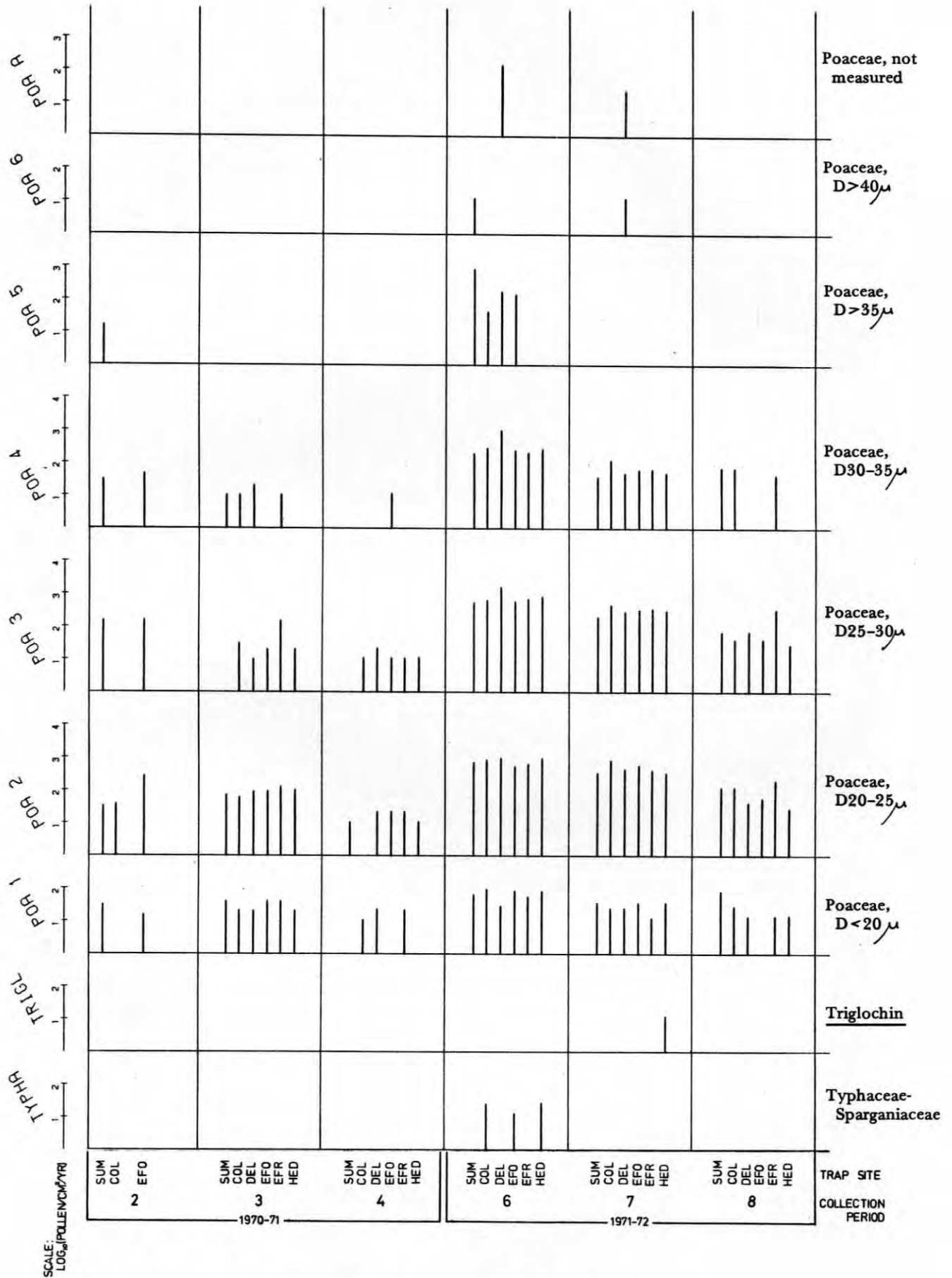


FIG. 4.8 ALPINE POLLEN TRAPS PDR DIAGRAM

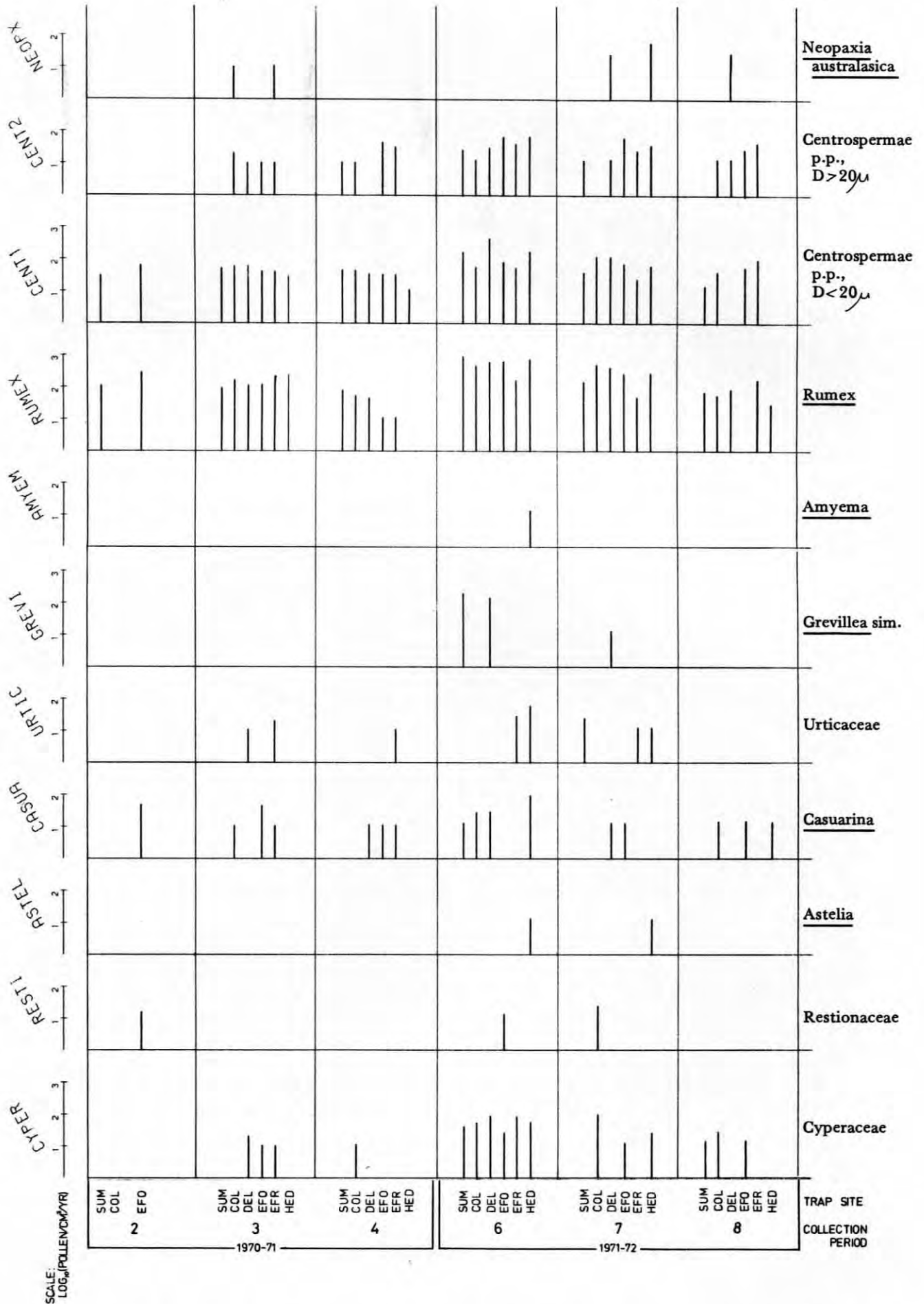


FIG. 4.8 ALPINE POLLEN TRAPS PDR DIAGRAM (continuation 1)

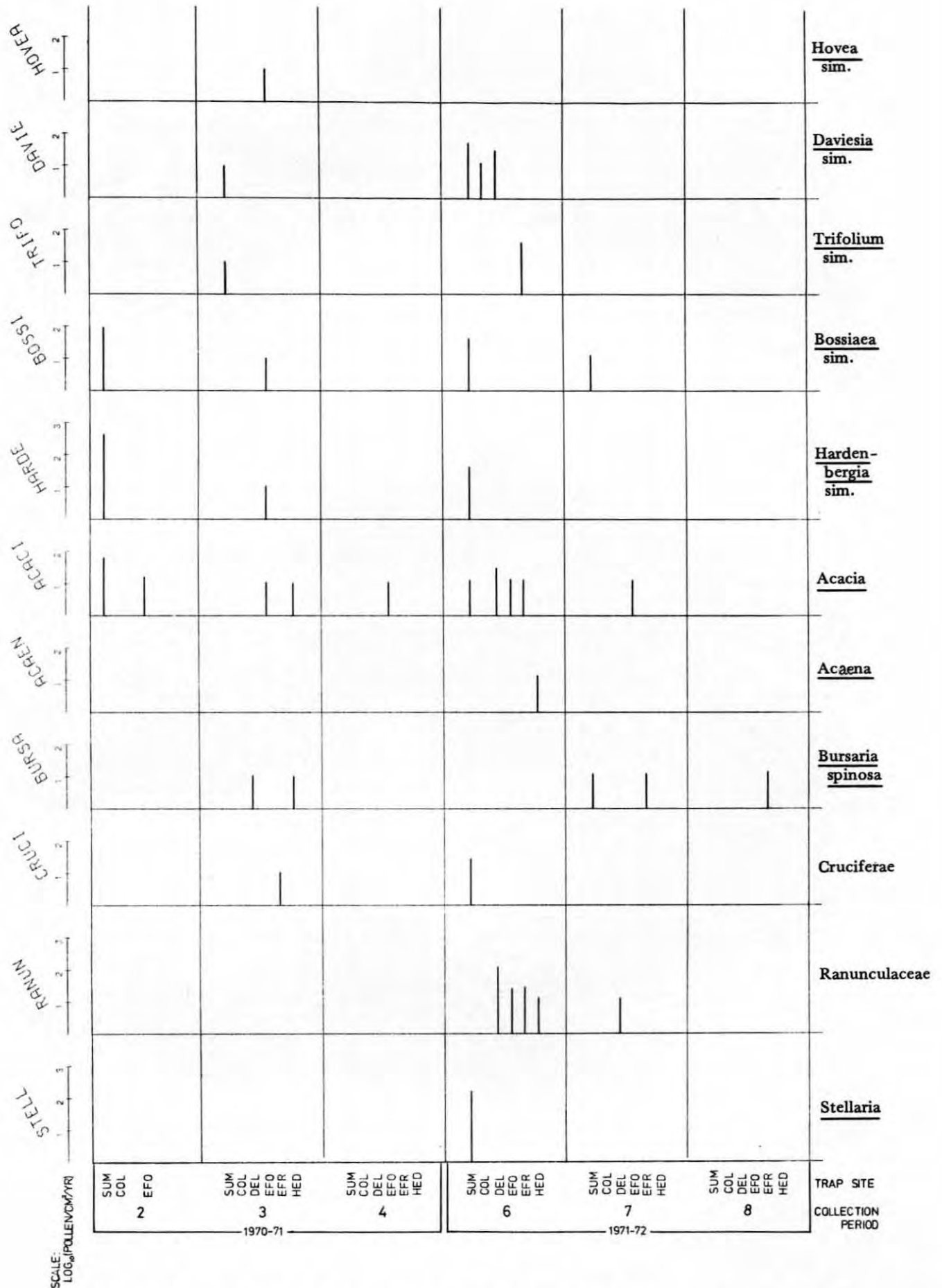


FIG. 4.8 ALPINE POLLEN TRAPS PDR DIAGRAM (continuation 2)

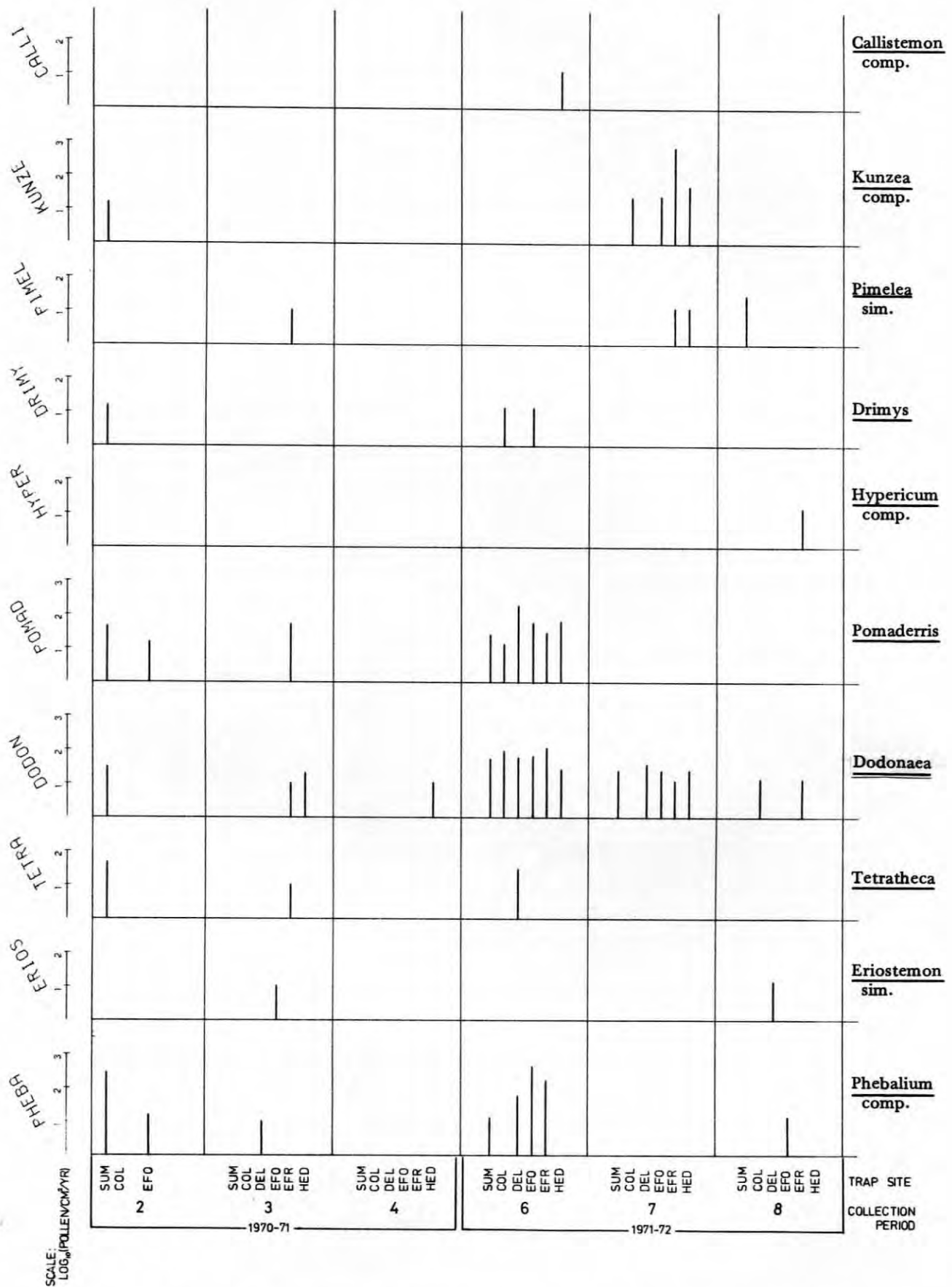


FIG. 4.8 ALPINE POLLEN TRAPS PDR DIAGRAM (continuation 3)

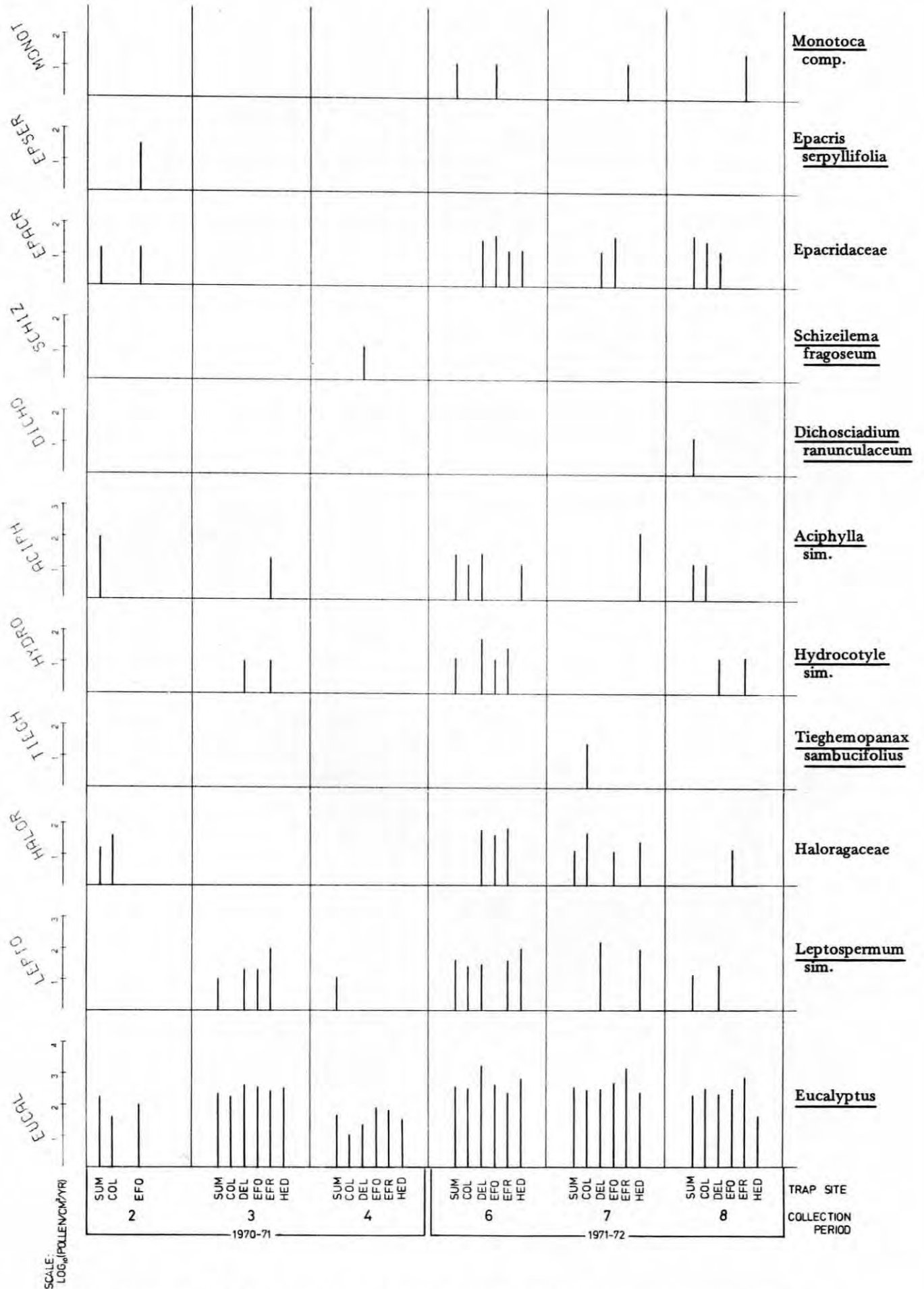


FIG. 4.8 ALPINE POLLEN TRAPS PDR DIAGRAM (continuation 4)

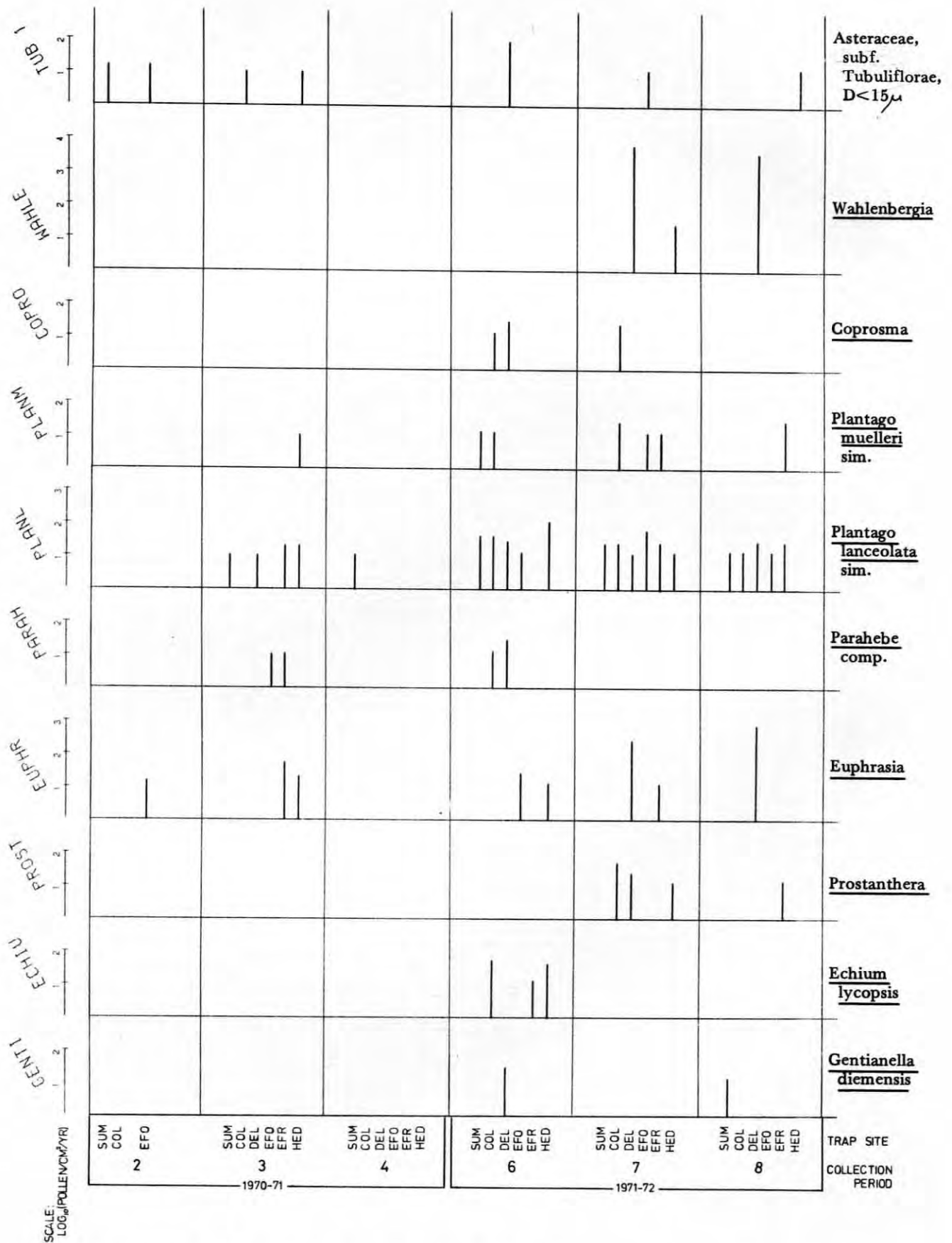


FIG. 4.8 ALPINE POLLEN TRAPS PDR DIAGRAM (continuation 5)

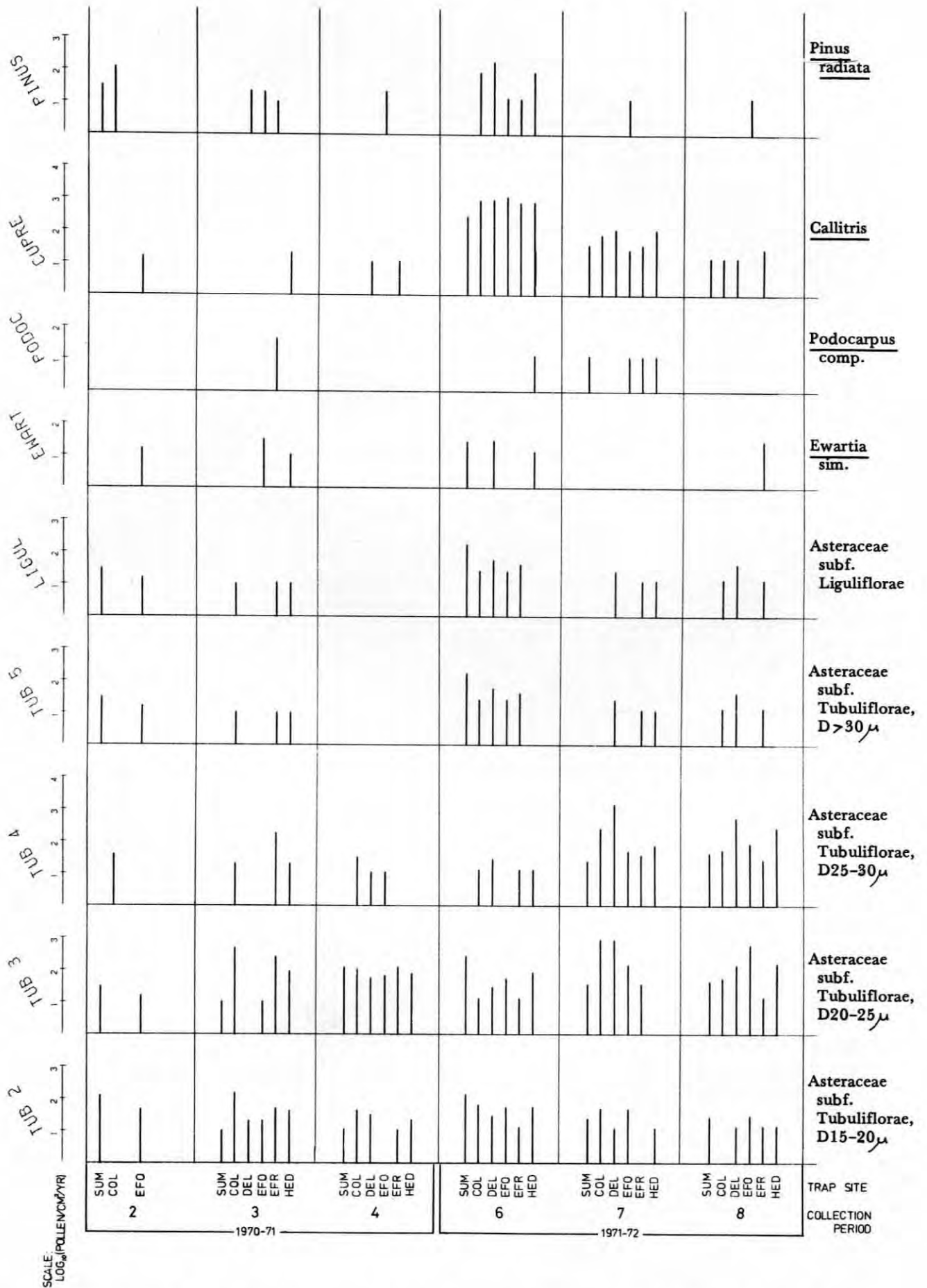


FIG. 4.8 ALPINE POLLEN TRAPS PDR DIAGRAM (continuation 6)

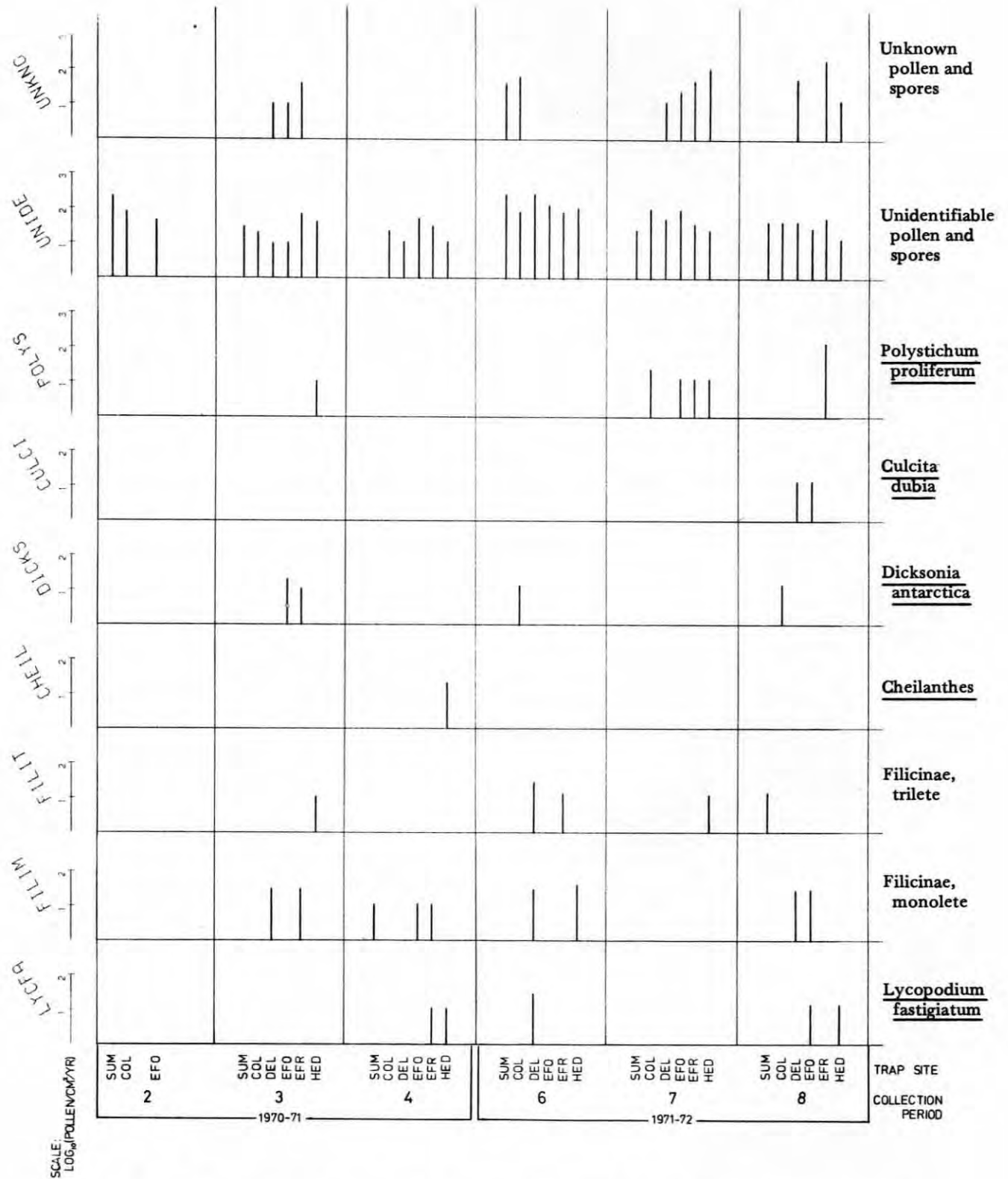


FIG. 4.8 ALPINE POLLEN TRAPS PDR DIAGRAM (continuation 7)

sim., Hardenbergia sim., Stellaria, Kunzea comp. (?), Phebalium comp. (?), Aciphylla sim. (?), Euphrasia, Wahlenbergia, Inclusion of these taxa in the pollen sum for calculation of RPF has distorted the diagram, but since the PDR diagram is available, it was not considered worthwhile excluding them.

Within each season, trap catches correspond fairly well to peak flowering periods. Most non-alpine taxa have highest PDR in the earliest trap periods: these include Acacia, Papilionaceae, Pomaderris, Dodonaea, Pinus, Callitris and Typhaceae. Eucalyptus, however, does not decline so markedly, in accord with the late summer flowering period indicated by the Geehi Valley traps. The early-flowering alpine taxa Ranunculaceae and Phebalium are most frequent in the early periods, while Kunzea and Asteraceae (D20-30 μ) have peak frequencies later. Asteraceae subfamily Liguliflorae and Asteraceae (D<20 μ , D>30 μ) peak early, suggesting their origin is mainly outside the strictly alpine area, although the latter may include some shrub taxa, tall heath tending to flower early in the alpine season.

Comparison of results from different trap sites in the same collection period has yielded no unequivocal trends. For example, Daviesia sim. is present in traps closer to the tree-line, whereas Pomaderris and Kunzea show no greater frequency in these traps. Among other taxa, Eucalyptus PDR also appears to show no relationship to distance from the treeline, nor to relative windiness of trap site.

General observations on pollen trap results

i) Seasonality of pollen production

Times of peak PDR in various taxa correspond well with observed flowering periods, and are in accord with pollen trapping studies by Australian allergists (Derrick, 1962; Mercer, 1941; Moss, 1965; Sharwood, 1935; Speck, 1953). In a study carried out in Canberra in 1956-59, Sands (1967) exposed adhesive-coated slides in a standard holder (Durham, 1946b), in a suburban area. Variation in total pollen count between the three sampling years was correlated with total annual rainfall, low pollen counts being associated with low rainfall, and vice versa. The distribution of periods of peak pollen collection for the various taxa was similar in each year, however, the main components being Poaceae (44%, peaking in spring to early summer), Cupressaceae (18%, peaking in late winter to early

spring), Plantago (14%, peaking in summer) and Pinus (12%, peaking in spring). Most of these are probably mainly local in origin. Minor components included Casuarina (peaking in early summer), Eucalyptus (late summer to autumn), and a number of garden taxa. Very little Acacia pollen was observed, Sands correlating its occurrence (spring-early summer) to raising of the heavy pollen by high winds. Spring to summer peak pollen production periods were also observed in many plant communities at Wilson's Promontory by Hope (1968).

Total pollen deposition for the Bella Vista trap in the first year of operation (periods 1-4) is of the order of 140×10^3 grains/cm² while for the second year it is about 20×10^3 grains/cm² (periods 5-9). The high apparent deposition in the first year is mainly due to great overrepresentation in certain taxa; the pollen deposition figures for many individual taxa are in fact lower than during the second year, confirming the trend seen in the alpine pollen traps. Variation in pollen catch between years has been noted by many authors (e.g. Sands, above). Since the pollen spectra of at least the Geehi Valley traps appears to be mainly local in origin, differences here seem to involve actual differences in production.

ii) Comparison of pollen deposition in alpine and forested areas.

As has been noted, there is greater inter-site and inter-period variation in the Geehi Valley trap results than in the alpine area trap results. This has been attributed to a greater proportion of locally-derived pollen at the former trap sites. This may be due to greater local production in the forested area, together with lesser wind mixing of pollen from different communities. Taking the mean of the alpine area results as a whole, for periods 6 to 8, the following figures are relevant:

	Pollen deposition (grains/cm ²)			
	Alpine	CCH	CCL	BEV
Total Poaceae	635	207	378	8565
<u>Casuarina</u>	7	6	12	0
<u>Rumex</u>	172	6	6	106
Centrospermae (D<20 μ)	50	30	30	0
<u>Pomaderris</u>	11	6	70	10
<u>Eucalyptus</u>	188	1525	1196	1460
Asteraceae (D<20 μ)	17	1576	73	1196
Asteraceae (D20-30 μ)	195	134	346	185
Asteraceae (D>30 μ)	13	30	37	3871
<u>Pinus</u>	12	12	6	11
<u>Callitris</u>	157	0	6	0
All taxa	2200	4130	3620	19220

Eucalyptus pollen deposition appears to have been similar at each forest site, though the timing of peak deposition differed between sites. This similarity suggests that insect contribution of Eucalyptus pollen may not be important, as if this were the case it might be expected that great variations would occur. In the alpine area, Eucalyptus pollen deposition is less than 1/7 of the mean forest trap deposition. Since the Geehi area is believed to be the main source of Eucalyptus pollen, if the measured deposition is typical of the area, then the contribution of other plant taxa growing there to the alpine pollen deposition would be at most 1/7 of their observed forest-area depositions. It might be considerably less if, as shown by Tauber (1967) for a forested area in Denmark, pollen escape from the forest understory (trunkspace component) is limited by impaction on leaves and branches, and by low wind speeds there. In any event, it would appear that the greater part of pollen of Poaceae, Rumex and Asteraceae (D20-30 μ) is not derived from the forested area. (The high deposition of Poaceae at the Bella Vista site is believed to be due to local clearance).

Pollen of long-distance transported components Casuarina, Centrospermae (D<20 μ), and Pinus has similar deposition in both alpine and forested areas, as would be expected, but the value for Callitris is surprisingly low. The nearest extensive areas of Callitris woodland are to be found in the rain-shadow area of the lower Snowy River valley, approximately 40 km to the

south-east of Blue Lake. It is possible that meteorological conditions favouring transport of Callitris pollen from this area did not extend to the west of the divide. That rainfall restricted to the alpine area is not the sole explanation for the difference can be seen by comparison of the alpine area roofed and unroofed Efflux pollen traps: although Callitris deposition was lower in the roofed trap, it was still appreciable.

Forest trap deposition of Asteraceae ($D < 20\mu$) and Asteraceae ($D > 30\mu$) was sufficiently large, although erratic, to suppose that a large part of the alpine deposition of these pollen types during the trapping period may have originated from forested areas. The position is less certain than with the previously mentioned taxa.

iii) Magnitude of annual pollen deposition in the forest area.

Estimates are complicated by the occurrence of pollen contributed by insects, and possibly also by litter and actual flower parts. Observed figures were:

Bella Vista, 1970-71 (periods 1-4)	136875 g/cm ² /yr
" " 1971-72 (periods 5-9)	20482 g/cm ² /yr
Claymore Ck. High "	5412 g/cm ² /yr
Claymore Ck. Low "	5159 g/cm ² /yr

Deduction of the pollen contribution apparently originating in the disturbed area about the Bella Vista site brings 1971-72 figures for this site close to the Claymore Creek figures. It is concluded that the annual pollen deposition rate is of the order of 5000 grains/cm². Loss due to filtering by the open Eucalypt forest canopy does not appear to be important in determining the magnitude of deposition at sub-canopy levels.

iv) Magnitude of summer season pollen deposition in the alpine area.

Observed figures were (in grains/cm²):

	1970-71 (periods 2-4)	1971-72 (periods 6-8)
Summit	560	1520
Col	440	1790
Delta	730	4850
Efflux Open	530	1680
Efflux Roofed	550	1750
Hedley Tarn	320	1590

The 1970-71 figures for the Delta, Efflux Roofed and Hedley Tarn sites refer to trap periods 3 and 4 only, thus do not include the early period of higher pollen deposition. Late-season pollen deposition rates are low, thus the best estimate of aerial pollen influx to Blue Lake during the 1970-71 ice-free season is about 550 grains/cm².

In the 1971-72 season results the figure for the Delta site is greatly increased by insect-contributed Wahlenbergia pollen. Lake ice-over occurred close to the date of pollen trap removal. The best estimate that can be made of aerial pollen influx to Blue Lake during this season is about 1700 grains/cm².

v) Magnitude of the rainout component of summer alpine pollen deposition

In the case of the roofed and unroofed Efflux traps, no systematic difference in the total size of the pollen catch could be distinguished but deposition of possible long-distance transported taxa appears to have been greater in the unroofed trap, as indicated in the table below. Pollen of these taxa could be expected to be carried to greater altitudes, and thus perhaps be important in the rainout component.

	Pollen Deposition (grains/cm ²)			
	Σ Periods 3 & 4		Σ Periods 6,7,8.	
	Open	Roofed	Open	Roofed
<u>Casuarina</u>	12.3	4.8	4.9	-
<u>Callitris</u>	-	2.4	212.3	142.8
<u>Pinus</u>	9.9	2.4	7.2	2.4
Centrospermae (D<20μ)	17.3	16.8	39.1	31.7
<u>Eucalyptus</u>	108.0	77.1	229.7	195.8
Total PDR (all taxa)	320	550	1680	1750

Examination of other trap results, however, reveals lower pollen deposition of some of these taxa than in the roofed trap. It is concluded that, although there may be a rainout component, its magnitude cannot be estimated from the above data, and is in any case small (probably less than 10%).

Rainout components observed by other workers include (as percentages of total pollen caught in unroofed Tauber traps):

Tauber (1967)	12%
Berglund (1973)	10-40%
Hope (1973)	68-95%

Tauber's and Berglund's trap sites were in open areas in mixed broad-leaf and coniferous forest in Denmark and southern Sweden, while Hope's were located in alpine, subalpine and forested montane areas in New Guinea. Hope suggests that the high rain-out component in his New Guinea sites is probably due to the high frequency of afternoon rain in that humid tropical mountain area, which tends to clean the air on a daily basis and to carry pollen back to ground level. Rain frequency is possibly also greater at the Scandinavian sites of Tauber and Berglund than in the summer period in the Snowy Mountains.

SNOW CORES

Snow sampling was carried out at the end of each winter season, on the first occasion a month before lake ice break-up, on the second within a few days of this event. Duplication of sites was not possible, owing to the different snow accumulation and melting patterns: some original sites were bare in the second sampling period. On each occasion four average snow accumulation sites were chosen, including one on the lake surface, to allow for variation in pollen deposition from place to place. It would have been possible to take all samples from the lake surface, but it was felt that the possibility of partial melting of the lake snow/ice cover from below, with subsequent loss of entrapped pollen, was an unknown quantity.

Details of sample counts are given in Appendix D, Table D.7. Total deposition per unit area has been tabulated for each core. With cores 1, 3 and 4 in 1970 the bottom sections of core were discarded, because of soil contamination, so that pollen deposition estimates for these cores are minima. Since pollen concentration generally decreased with depth, these estimates may not be greatly in error from this cause. The exception to this general trend was core 2, 1971, in which the bottom section had a pollen concentration and spectrum very similar to the top of the core. This core appeared to bottom on ice: no soil contamination was observed.

A resolved RPF diagram is presented in figure 4.9. Important pollen taxa include Poaceae, Rumex, Centrospermae, Eucalyptus, Asteraceae and Pinus. Indubitably alpine taxa include Astelia, Neopaxia, Phebalium, Aciphylla sim., and Lycopodium selago: all these have low RPF, and low pollen deposition per unit area, as shown by the resolved pollen deposition diagram, figure 4.10. Taxa mainly referable to alpine plant communities include Cyperaceae, Restionaceae, Ranunculaceae, Cruciferae, Epacridaceae, Euphrasia, Plantago muelleri sim., Ewartia sim. and Lycopodium fastigiatum, with low RPF, and Rumex and Centrospermae ($D > 20\mu$) with moderate RPF. Other taxa are attributable to forest communities, or are universal, with the exception of the long-distance transported taxa Casuarina, Centrospermae ($D < 20\mu$), Gyrostemonaceae, Angophora, Echium lycopsis, Myoporaceae, Callitris and Pinus.

There appears to be little systematic variation in RPF within the cores. High Rumex count in the lower section of core

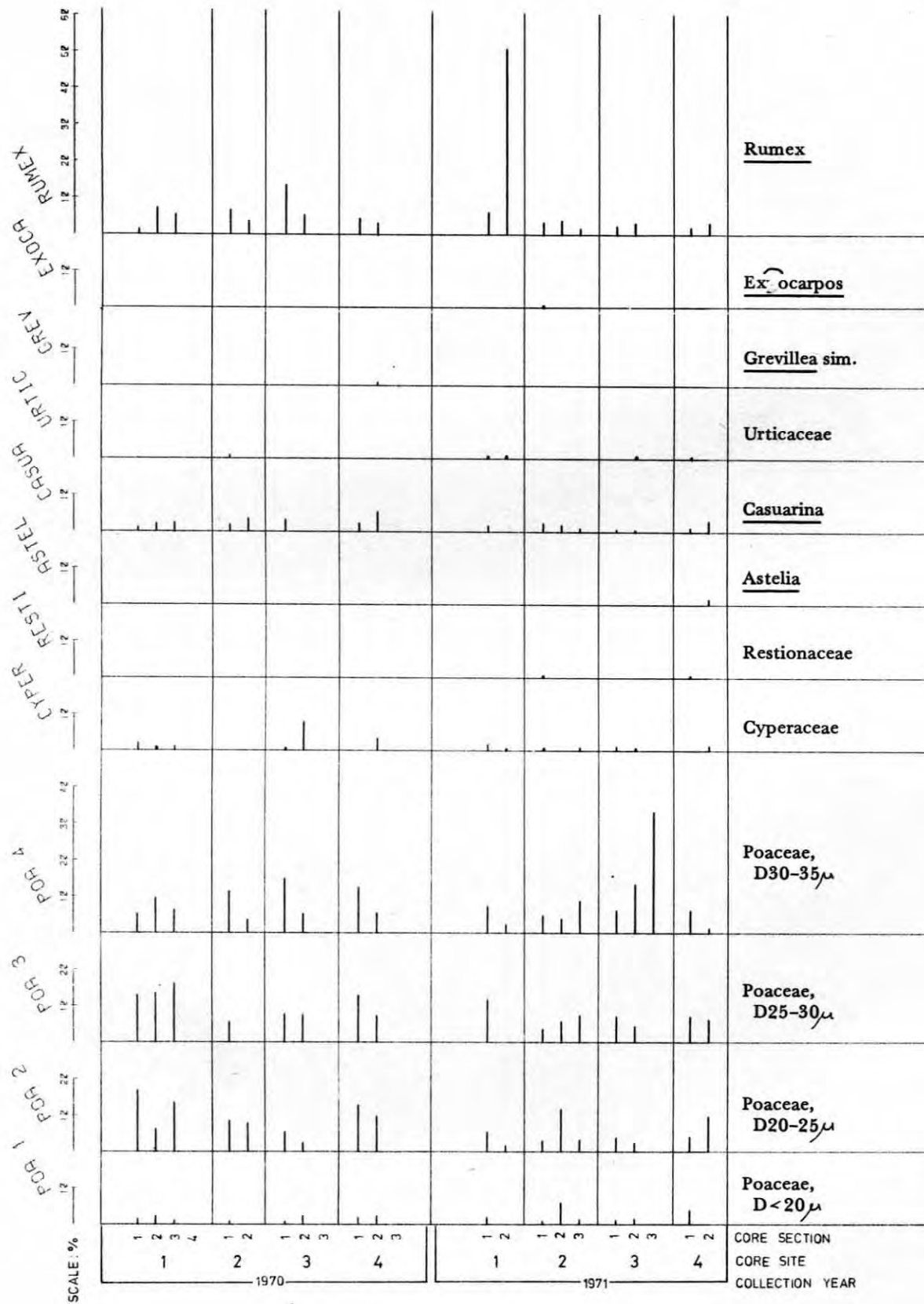


FIG. 4.9 SNOW CORES RPF DIAGRAM

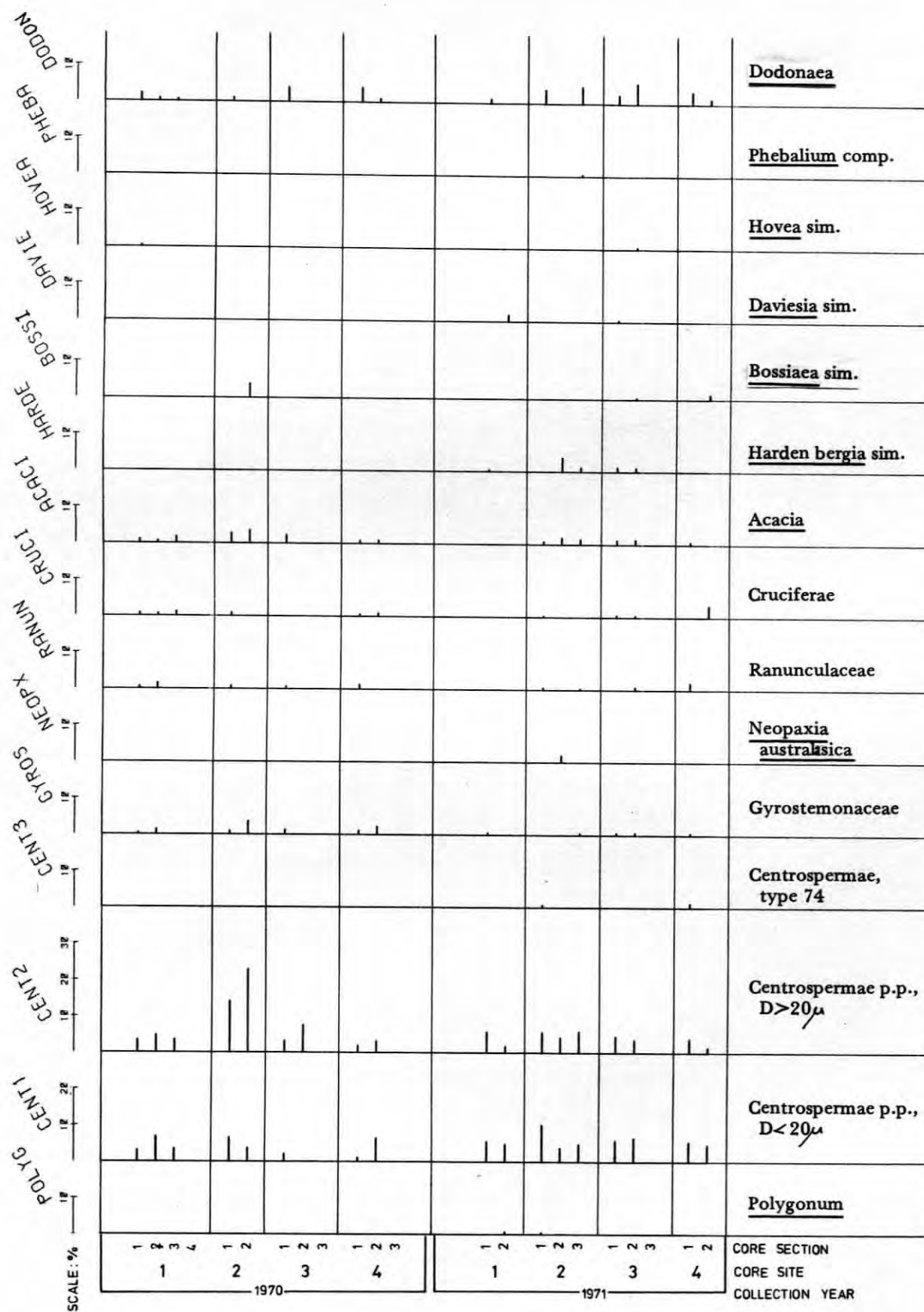


FIG. 4.9 SNOW CORES RPF DIAGRAM (continuation 1)

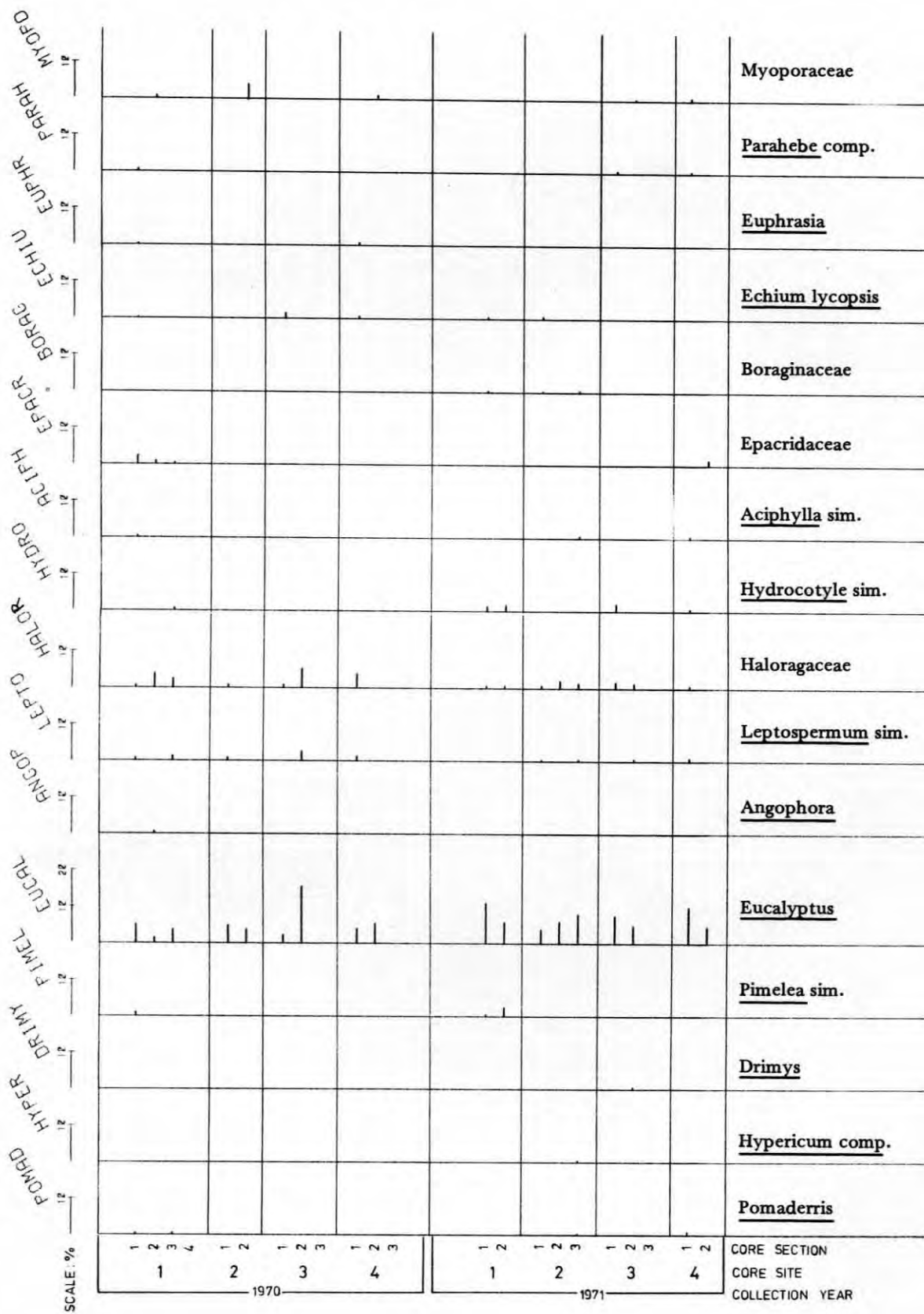


FIG. 4.9 SNOW CORES RPF DIAGRAM (continuation 2)

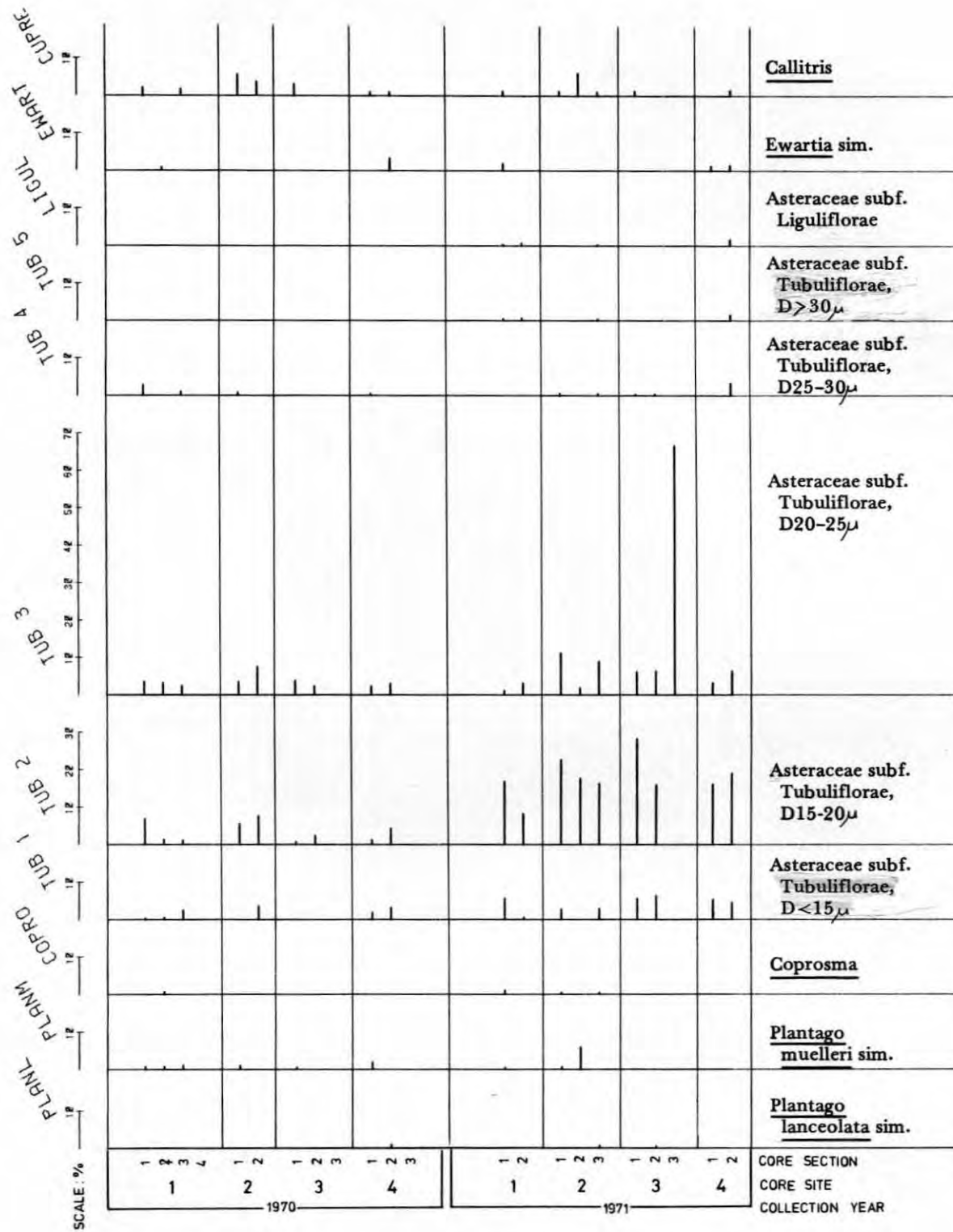


FIG. 4.9 SNOW CORES RPF DIAGRAM (continuation 3)

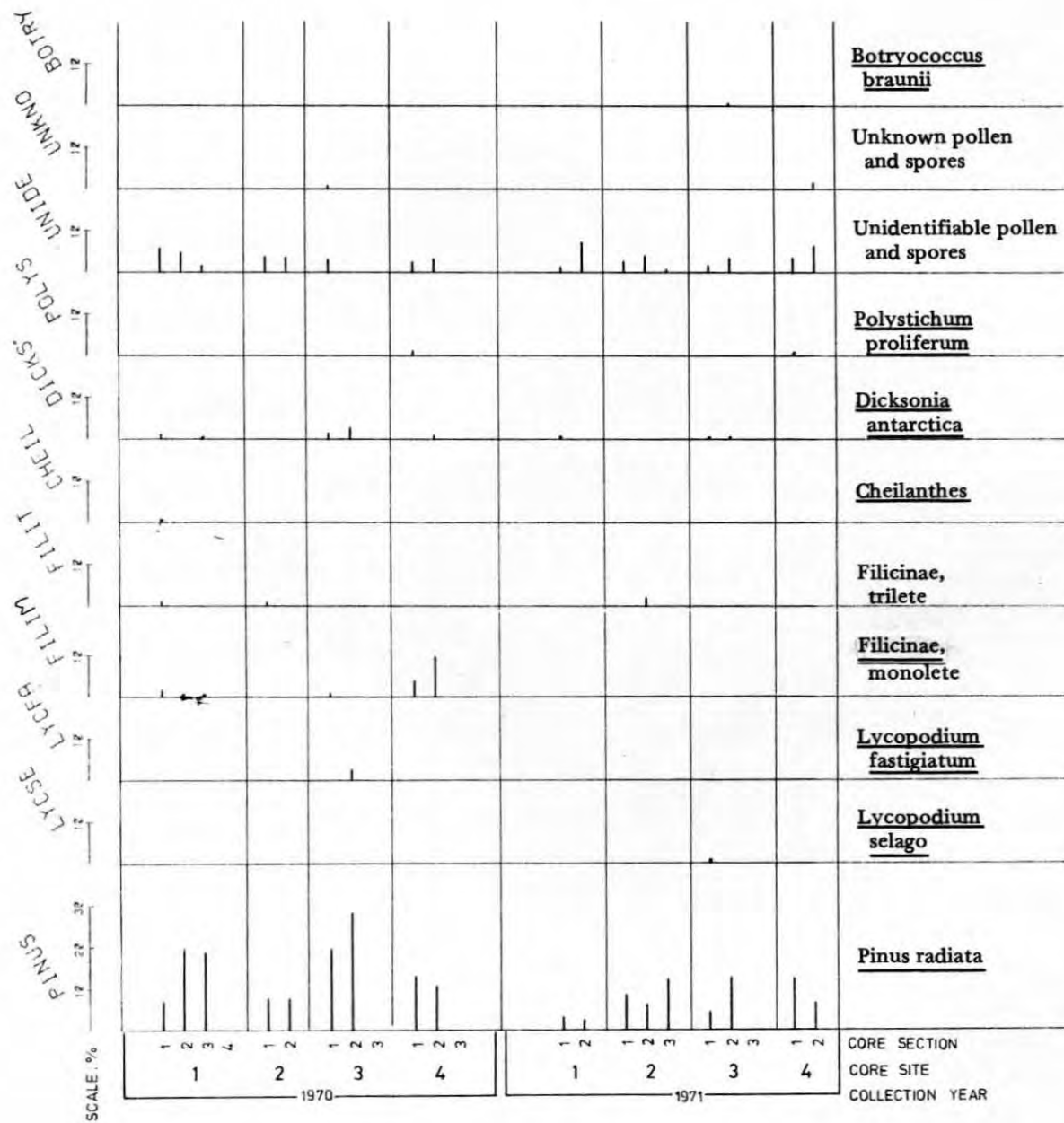


FIG. 4.9 SNOW CORES RPF DIAGRAM (continuation 4)

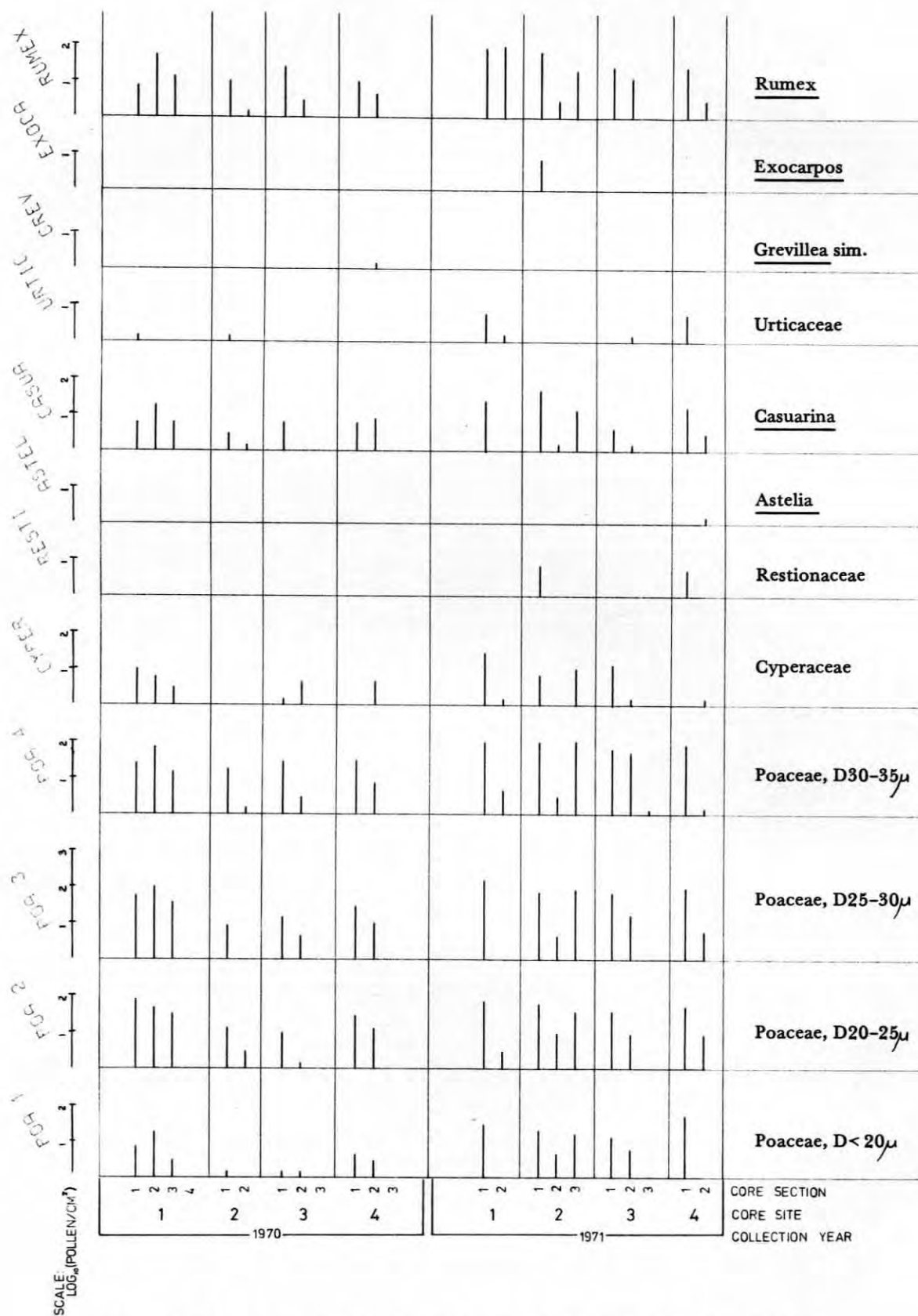


FIG. 4.10 SNOW CORES POLLEN DEPOSITION DIAGRAM

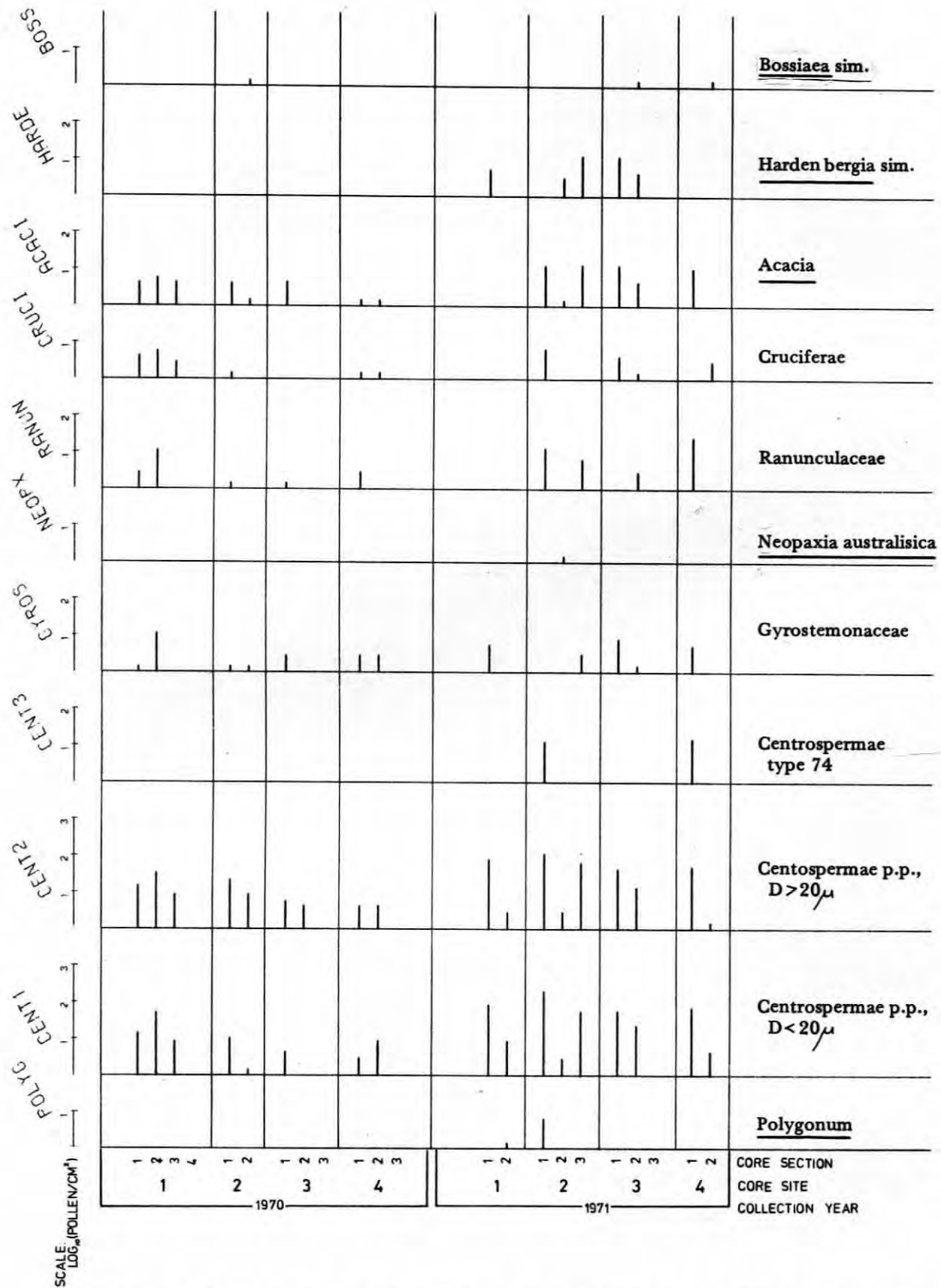


FIG. 4.10 SNOW CORES POLLEN DEPOSITION DIAGRAM (continuation 1)

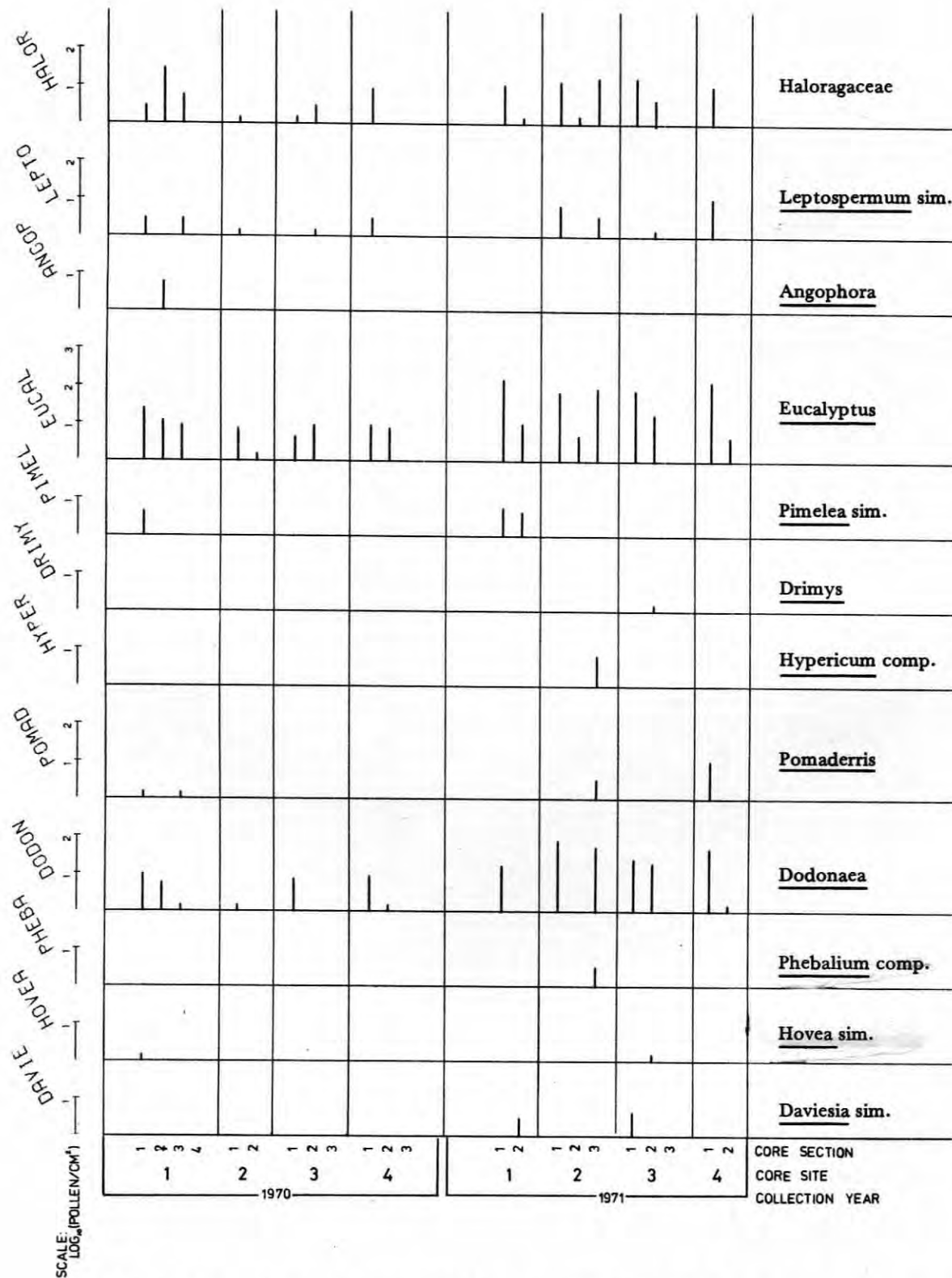


FIG. 4.10 SNOW CORES POLLEN DEPOSITION DIAGRAM (continuation 2)

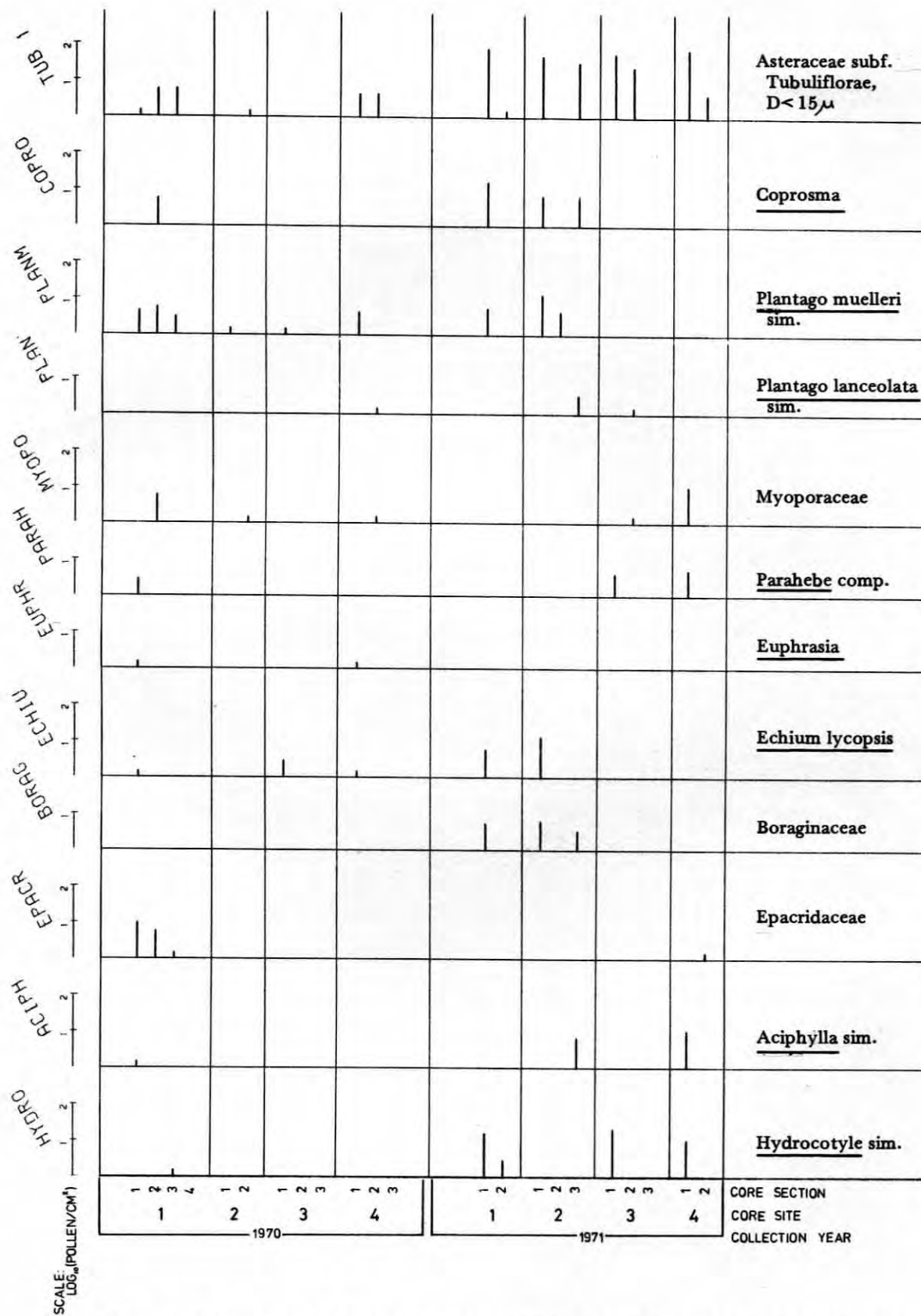


FIG. 4.10 SNOW CORES POLLEN DEPOSITION DIAGRAM (continuation 3)

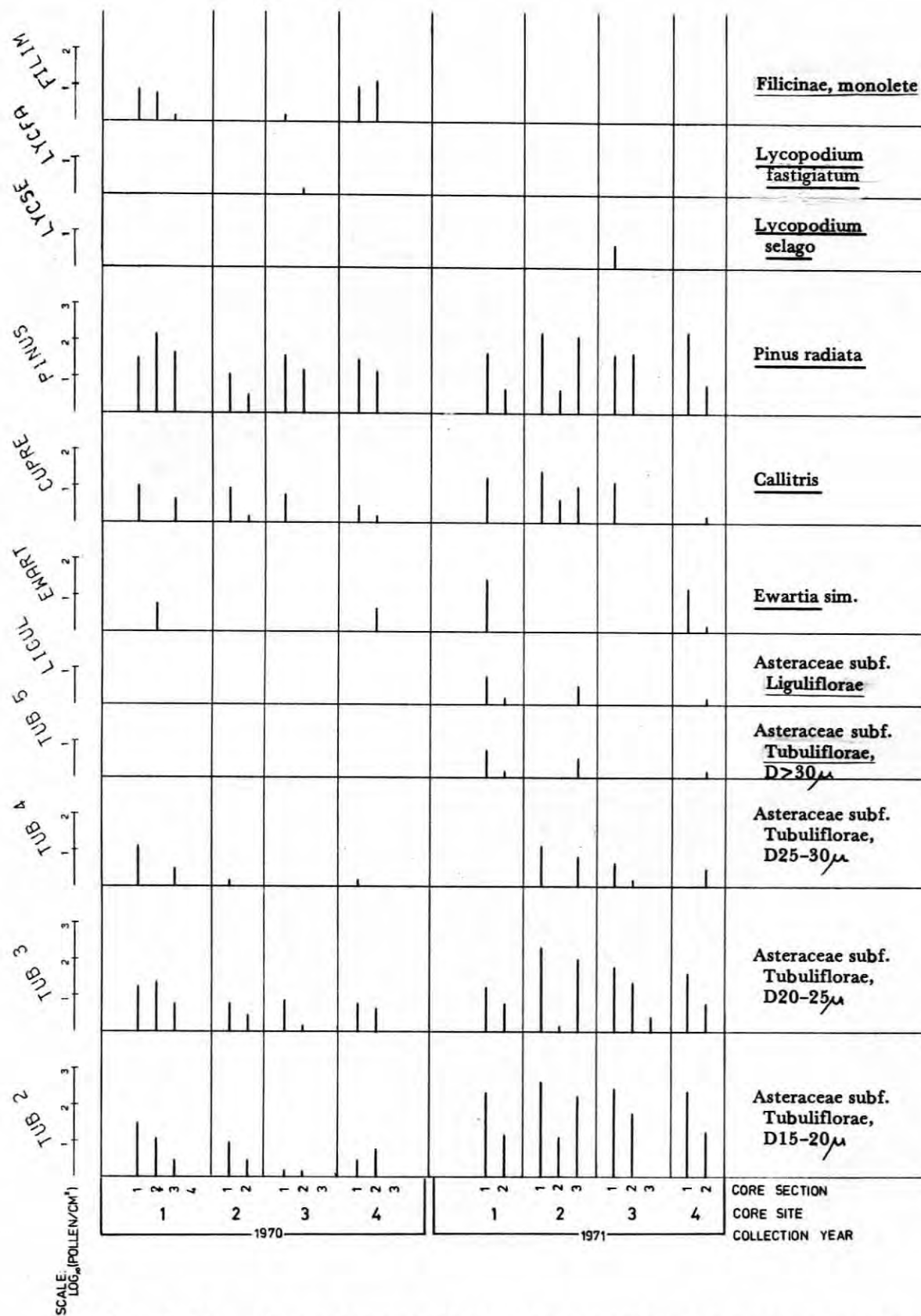


FIG. 4.10 SNOW CORES POLLEN DEPOSITION DIAGRAM (continuation 4)

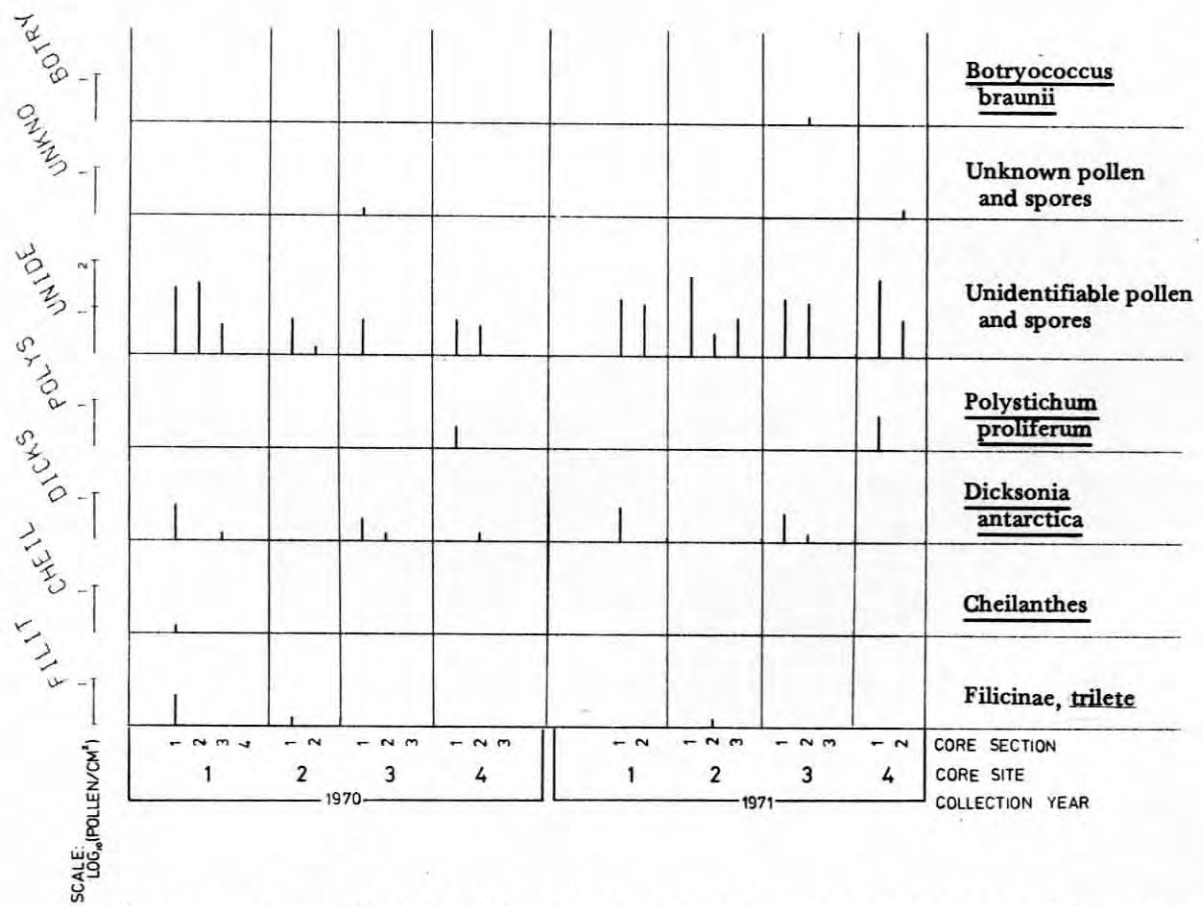


FIG. 4.10 SNOW CORES POLLEN DEPOSITION DIAGRAM (continuation 5)

1, 1971, suggests incorporation of actual flower parts. Some other high relative frequencies are due to chance occurrence in a small total number of pollen counted.

In comparing one core with another, within each season's samples, there do appear to be some significant variations. For example, core 2, 1970, appears to have higher RPF of Centrospermae ($D > 20\mu$), Acacia, Asteraceae and Callitris, with lesser Pinus and other taxa. Examination of the pollen deposition diagram indicates that deposition figures for the former taxa are not higher than those of other cores. The most likely explanation is that certain layers richer in the less frequent taxa are missing from the core, probably the uppermost ones. This site differed from all others in being steeply sloping, hence may have suffered erosion from snow sliding or surface wash. Slight differences in Pinus RPF between cores may similarly be due to partial erosion of the snow pack. Generally, however, relative pollen frequencies within each season are rather similar, despite great differences in pollen concentration.

General differences between the two year's samples include higher RPF of Eucalyptus and Asteraceae, particularly the 15-20 μ diameter range, and lower RPF of other taxa in the 1971 samples. The pollen deposition diagram shows that there was higher deposition of all taxa in 1971. In part the higher deposition, particularly of Eucalyptus, may be attributed to a later sampling time, but higher pollen deposition rates in alpine traps during the second summer season suggest that pollen influx into the alpine area may have been higher in the latter part of 1971. There is some support for higher pollen deposition in the montane area at this time from the Bella Vista pollen trap.

Discussion

Some factors possibly operating to produce the observed pollen distributions have been mentioned above. With others, these are considered in turn below.

- i) Re flotation of pollen by wind and snow scouring of alpine surfaces, including vegetation, not covered by snow. There seems no alternative explanation for the occurrence of pollen of alpine taxa in the snow. Since the taxa identified as alpine represent only a minor component of pollen deposited on vulnerable surfaces, their occurrence must be accompanied by an

appreciable amount of pollen of more common taxa from the same source. The effect would be expected to be most important during periods of partial snow cover, mainly at the beginning of snow accumulation in May, and thaw in October-November. It affords an explanation for the high concentration of pollen in the lower section of core 2, 1971. Relative importance of this component may vary from site to site, depending on the disposition of source areas, and from year to year, depending on snow cover, source area load, etc.

- ii) Entrapment on the snow surface, or deposition with the snow, of pollen originating in non-alpine areas. From the taxa involved this may include a variety of vegetation types, from wet sclerophyll forest to semi-arid mallee. That the latter is a winter source is shown by the occurrence of Gyrostemonaceae pollen, not recorded in alpine area pollen traps.

Bearing on winter-spring long distance transport of pollen is the demonstration by Walker and Costin (1970) of significant accession of atmospheric dust to alpine soils in the Kosciusko area. Following extensive dust storms in central Australia in October, 1968, a dust cloud passed over the eastern states, discolouring snow to a depth of 10 cm, and causing 'pink rain' to fall in Canberra. Particle size-analysis of dust collected from the 1968 snow, and from a raingauge in Canberra in October, 1967, when similar dust clouds were observed, showed that 75% of the dust was finer than 15μ , and that the median grain-size was close to 4μ . While this is finer than most pollen grains, these have a lower density when air-dry, and behave in a manner similar to that of smaller mineral dust particles, thus associated transport of pollen is likely.

Dust storms of sufficient magnitude to observably affect the eastern highlands of Australia occurred in the period 1938 to 1940 (Loewe, 1943), in 1902 and October 1928 (Marshall and Kidson, 1929) and before inland settlement (Lewis, 1950). Other occurrences may not have been recorded, while lesser occurrences

have probably been more frequent, and there may be such each year.

Meteorological conditions associated with the dust storms of October 1928, when dust was transported to New Zealand, have been analysed by Healy (1970). From contemporary press reports of the occurrence of dust storms, and its typical red colour, the dust reaching New Zealand appears to have originated in the Mallee-Wimmera-Riverina region of inland south-eastern Australia. From the high speed of transport of this dust, Healy postulates that it travelled at mid to upper-troposphere levels in the jetstream, after being raised to sufficient altitude by strong vertical winds associated with a cold front. Significantly, of the duststorms described by Loewe (1943), many occurred in association with the passage of a cold front across the area described above. Transfer of dust from the upper atmosphere appears to have occurred in the zone of decelerating and subsiding air at the leading edge of a wave trough; deposition was aided by strong down-draughts associated with cumulo-nimbus clouds related to the passage of the trough.

While it is not necessary to invoke the jetstream to transport dust to the Australian Alps, dust deposition in this area similarly appears to be associated with precipitation from strongly convective clouds. The higher rate of dust deposition in the Kosciusko area compared to Canberra, as observed by Walker and Costin (1970), could be explained by greater tapping of the upper tropospheric level of the atmosphere by orographically induced turbulence in this area.

The relevance of these observations is that a process exists which could conceivably deposit amounts of pollen from distant areas in excess of those to be expected from transport at low levels in the atmosphere. Thus Moar (1969) recorded Acacia, Eucalyptus, Pinus and Casuarina pollen in a 1969 snow sample from a high altitude in the South Island of New Zealand, Casuarina probably, and the other taxa possibly, having been transported more than 1600 Km from Australia.

Aartolahti and Kulmala (1969) have recorded a similar occurrence in Finland during the winter of 1968-1969 when dust-stained snow contained pollen believed to have been derived from steppe vegetation in the vicinity of the Sea of Azov, 1900 km away.

- iii) Erosion and redeposition of upper layers of snow by wind action. Because of the relatively high temperatures experienced in the Australian Alps, snow drift does not continue for more than one or two days after deposition of fresh snow. An ice crust forms in exposed areas after this time, effectively preventing transport. During the period of snow drift, probably about 10% of the time in the area above 1800m, pollen may be concentrated with the snow in areas of snow accumulation. This would be especially important when pollen was originally deposited with the snow, rather than merely being trapped on its surface.

The process may account for the high concentration of pollen in core 1, 1970, this being obtained from a site of greater snow accumulation. Core 1 from the same site in 1971 did not show the same degree of concentration, but it must be noted that snow depth relative to other sites was much less: possibly the core was taken at a slightly higher, thus more wind-swept, site in 1971.

- iv) Melting of the snow in contact with the ground beneath the snow pack. This is an unknown factor, but is known to occur in the vicinity of springs and streams even in the coldest months. It may account for the observation of probable autumn refloated pollen at only one site (core 2, 1971 - see i), above).
- v) Wash down of pollen through the snow by rain or ephemeral surface melt-water. This would be most likely to occur in spring. An unknown factor, but maybe not important as buried layers of ice crust in the snow would tend to retard rapid percolation necessary to transport pollen.
- vi) Concentration of pollen in the upper layers through differential surface melting and ablation. This certainly occurs, mainly in spring, and is probably the

main reason for the observed concentration of pollen in the upper layers of the cores. Increased spring influx of pollen, as noted previously, may also be important.

Summary

Many processes can be invoked to explain variations in snow pollen content from place to place and time to time. Because of possible losses through snow melt, the pollen deposition estimates must be regarded as minimum estimates, except in the case of core 2, 1971, where early season pollen appears to have been retained. In applying snow core measurements to lake pollen input estimation, possible differences in total pollen deposition between sites due to snow erosion and transport must be considered. Minimum and maximum estimates for total pollen deposition per unit area of lake snow surface, to dates of sampling, are:

Year	Estimated minimum	Estimated maximum	Observed mean of cores
1971	400	1500?	557 (grains/cm ²)
1972	1500	3000	1580 "

Pollen present in the snow arrives from a variety of sources, and includes components refloated from alpine and distant lowland areas, as well as nearby montane forest tracts.

LAKE SEDIMENT TRAPS

Siting of these is indicated in Fig. 4.1, and in more detail in Fig. 3.1. Traps were distributed about the lake to sample pollen sedimentation near the various potential pollen analysis core sites, to investigate possible variations in relative and absolute rates of sedimentation with place and time. Depths of the traps from the lake surface were:

LWB	6 m
LSB	10 m
LMB	19 m
LMT	5 m
LEB	12 m

With the exception of LMT, the traps were suspended 1.5 m above the lake floor; LMT, directly above LMB, was 16.5 m above the lake floor. Shallower depths were avoided because of the possibility of ice interference during winter.

Lake ice typically forms in the first weeks of June, and is permanent for the winter by the middle of the month. Snowfall increases the snow/ice cover on the lake surface to a maximum depth of 2-3 m, in September and October. Greater thicknesses may occur in snow-accumulation areas under the cliffs at the north-western end of the lake, and in exceptional winters (the maximum observed snow depth in the mountains is 4.3 m (Costin, 1961) . The lake snow/ice cover generally breaks up in late November-early December. The first step in this process is rotting of the ice from below in areas of winter movement, such as the influx and efflux stream mouths. When open leads appear, wind action causes break-up of the remaining ice and by driving water circulation aids melting, which is complete within about two weeks.

Results of thermal soundings of the lake during the trapping period are indicated in Fig. 4.11. Measurements were made with a thermistor instrument. During the period of ice-cover lake water temperatures drop to a maximum of 2°C, near the lake floor, with stratification. The period of post-thaw isothermal mixing (when water temperature is about 4°C, the temperature of maximum water density) is not closely known, but probably occurs in mid-December. Summer stratification is soon attained, maximum observed surface temperature being of the order of 14°C, maximum bottom temperature about 8°C. The depth

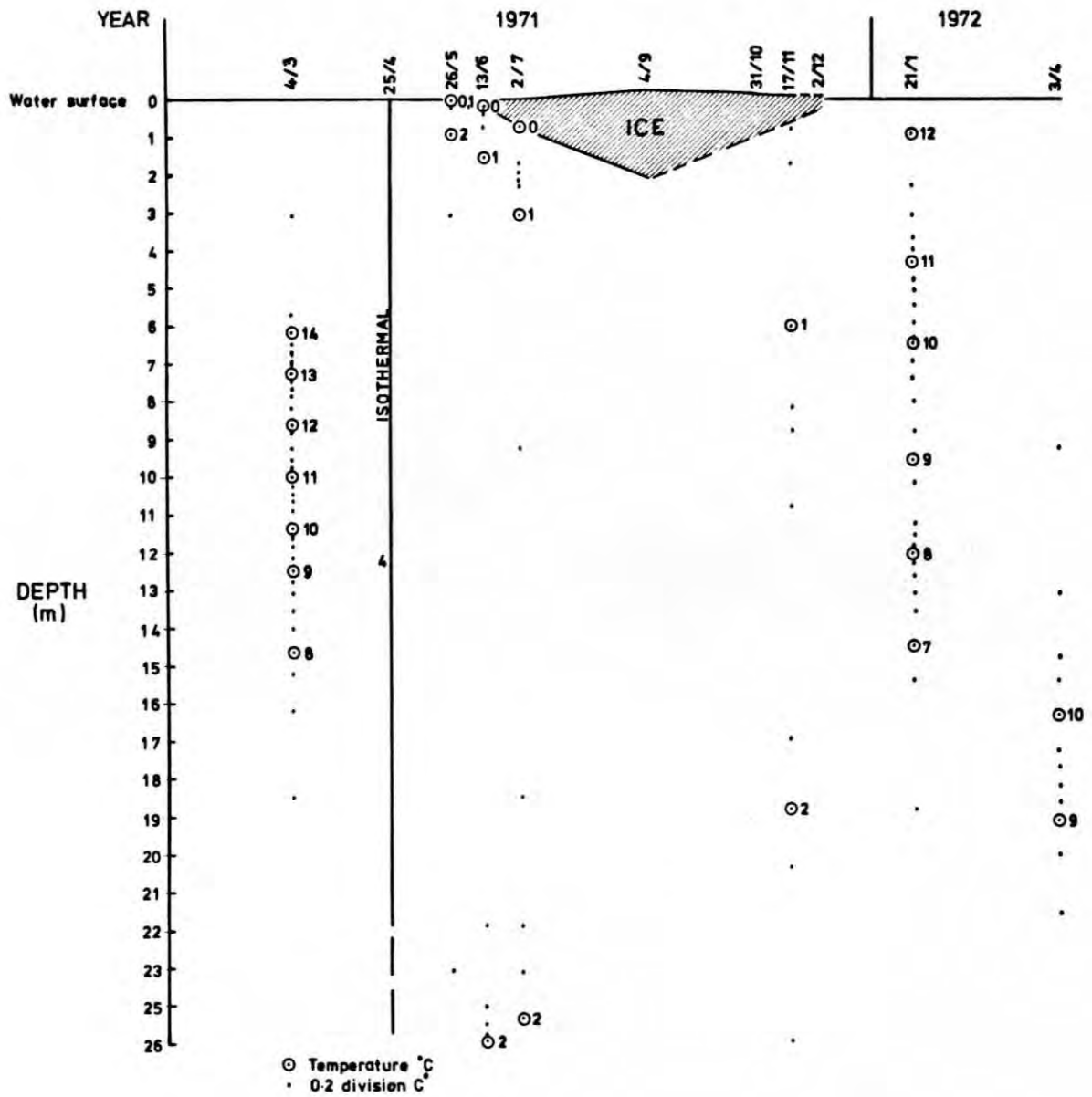


FIG. 4.11 THERMAL STRATIFICATION OF BLUE LAKE DURING PERIOD OF SEDIMENT TRAP OPERATION

to the thermocline (Hutchinson, 1957) appears to increase during autumn, possibly as wind velocities increase, but this is probably greatly dependent on the short-term wind regime. Autumn isothermal mixing occurs in late April or in May.

Because of early difficulties with sediment traps, suitable traps were not installed until 12.2.71 (see Chapter 2). During the first trap period, 12.2.71 to 24.4.71, the lake had summer thermal stratification except for a short while at the end, possibly one week. The second trap period, 24.4.71 to 21.1.72 covered both autumn and early summer periods of isothermal mixing, as well as the long period of winter stable stratification and a short period (about 1 month) of summer stratification. The last trap period, 21.1.72 to 3.4.72, was one of summer thermal stratification. Traps LWB and LMT were situated in the epilimnion (the layer of water with more or less uniform temperature in which wind-driven circulation occurs, above the thermocline) for an appreciable proportion of the period of summer stratification. Traps LSB and LEB were probably generally situated within the metalimnion (the region of the thermocline) while LMB appears to have remained in the hypolimnion (below the thermocline).

Processing of sediment trap contents is discussed in Chapter 2, while detailed results of pollen counts may be found in Appendix D, Table D.8. An RPF diagram is presented in Fig. 4.12, and PDR diagram in Fig. 4.13. Results are discussed in the light of some possible factors operative in deposition of pollen entering the lake.

i) Deposition (or at least trapping) of pollen near its source. This applies only to pollen derived from alpine vegetation growing around the lake, since the aerial deposition of pollen from more distant sources could be expected to be more uniform over the lake surface. If this were an important factor, alpine herbfield and heath pollen taxa would exhibit higher RPF in traps near the shoreline: (LWB, LSB, LEB) while pollen from distant sources would have higher RPF in the central lake traps (LMB, LMT). Ideal test taxa, plant species confined to the lake shore, do not occur. The only possible case is high Eucalyptus in the first summer period, trap LMT. It is likely that the effect, if operative, is obscured by other factors, to be discussed below.

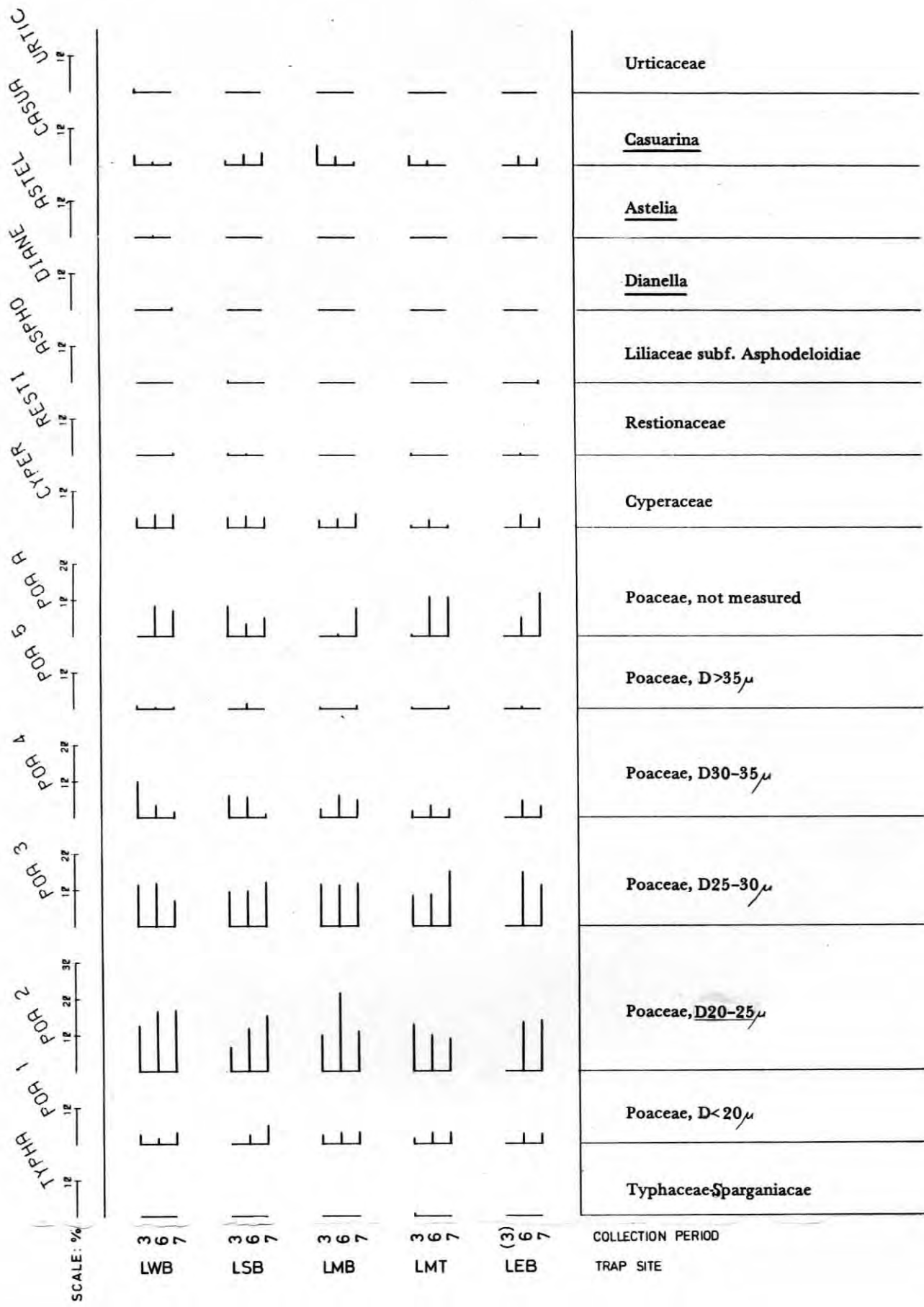


FIG. 4.12 LAKE SEDIMENT TRAPS RPF DIAGRAM

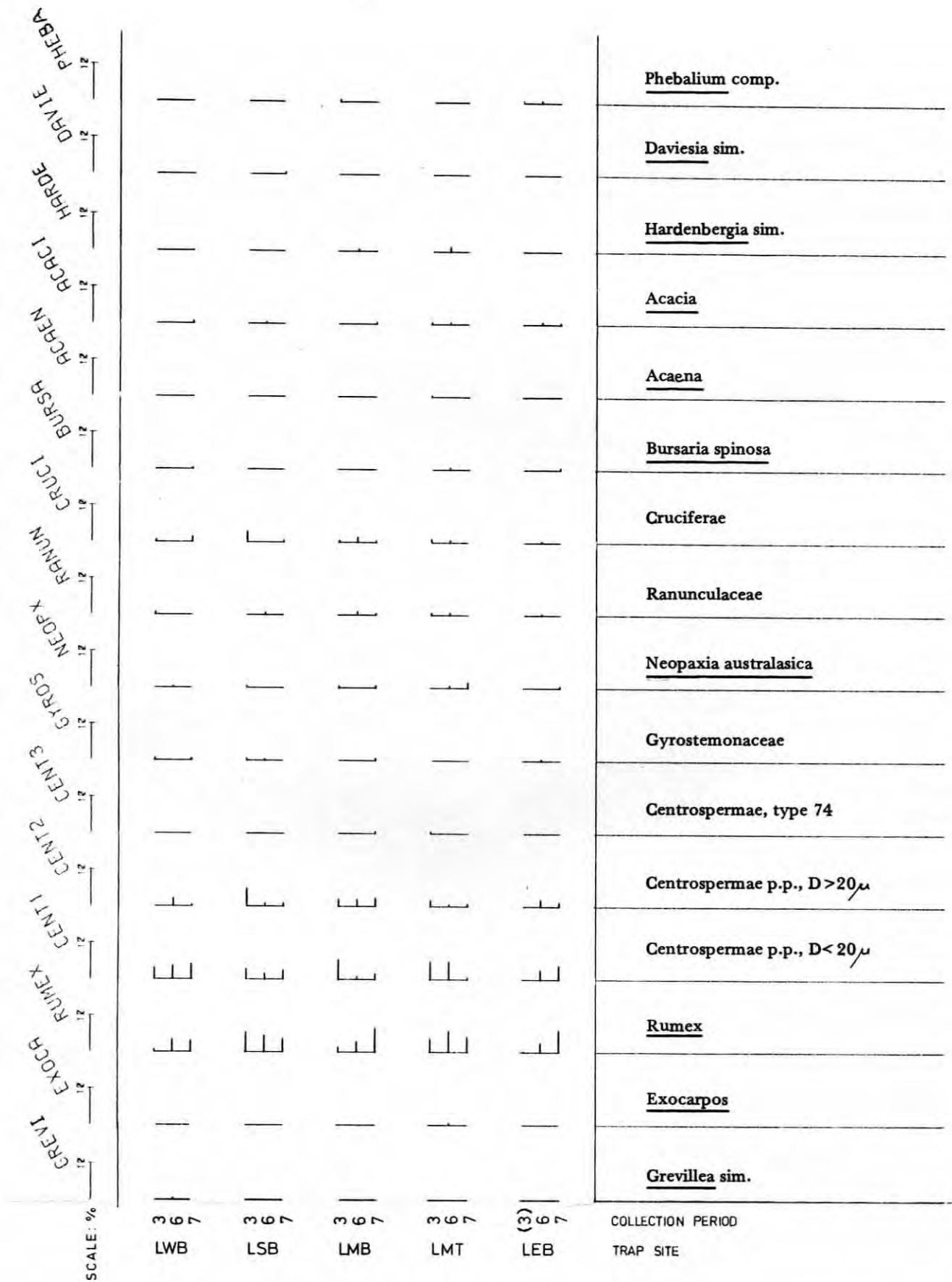


FIG. 4.12 LAKE SEDIMENT TRAPS RPF DIAGRAM (continuation 1)

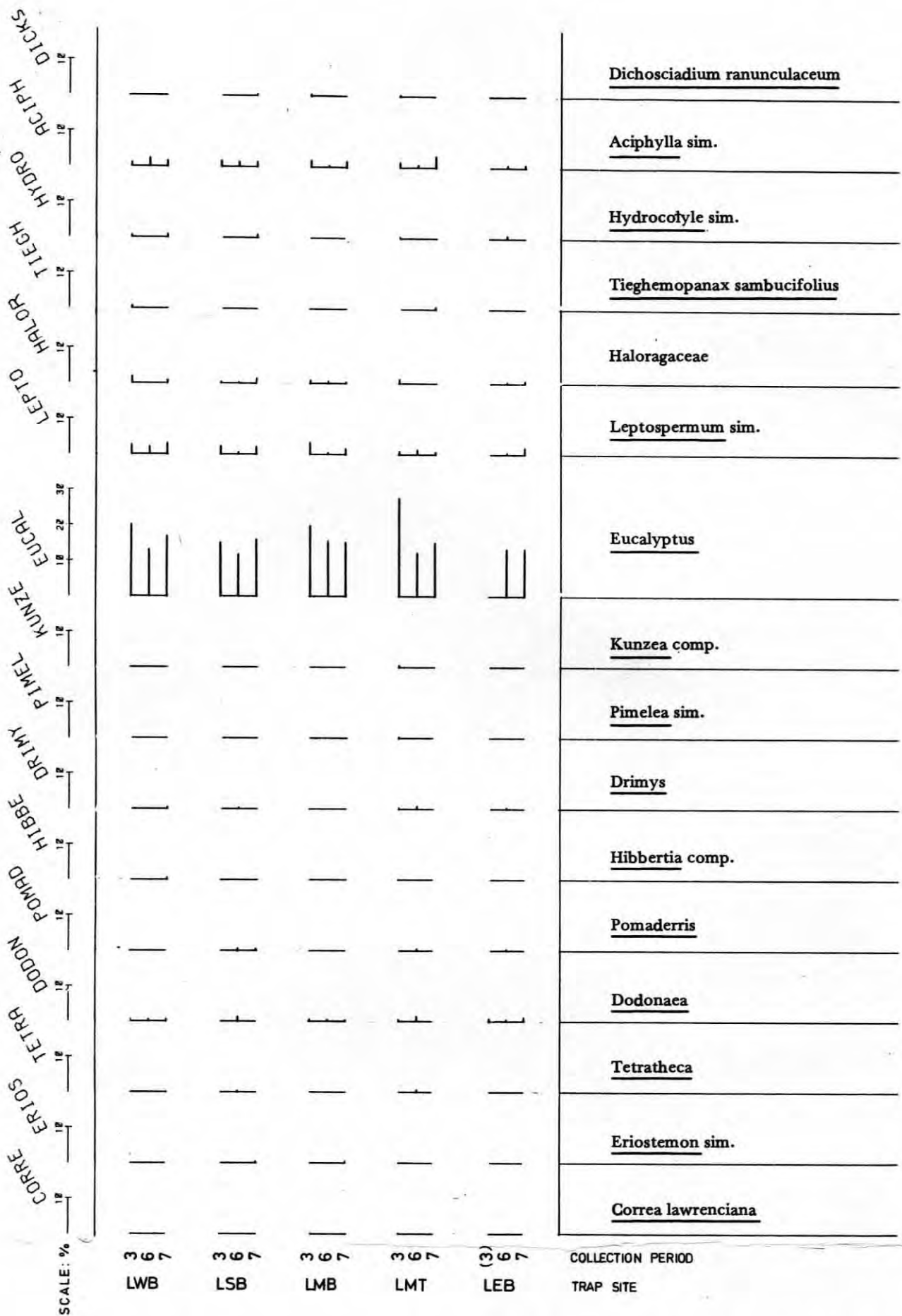


FIG. 4.12 LAKE SEDIMENT TRAPS RPF DIAGRAM (continuation 2)

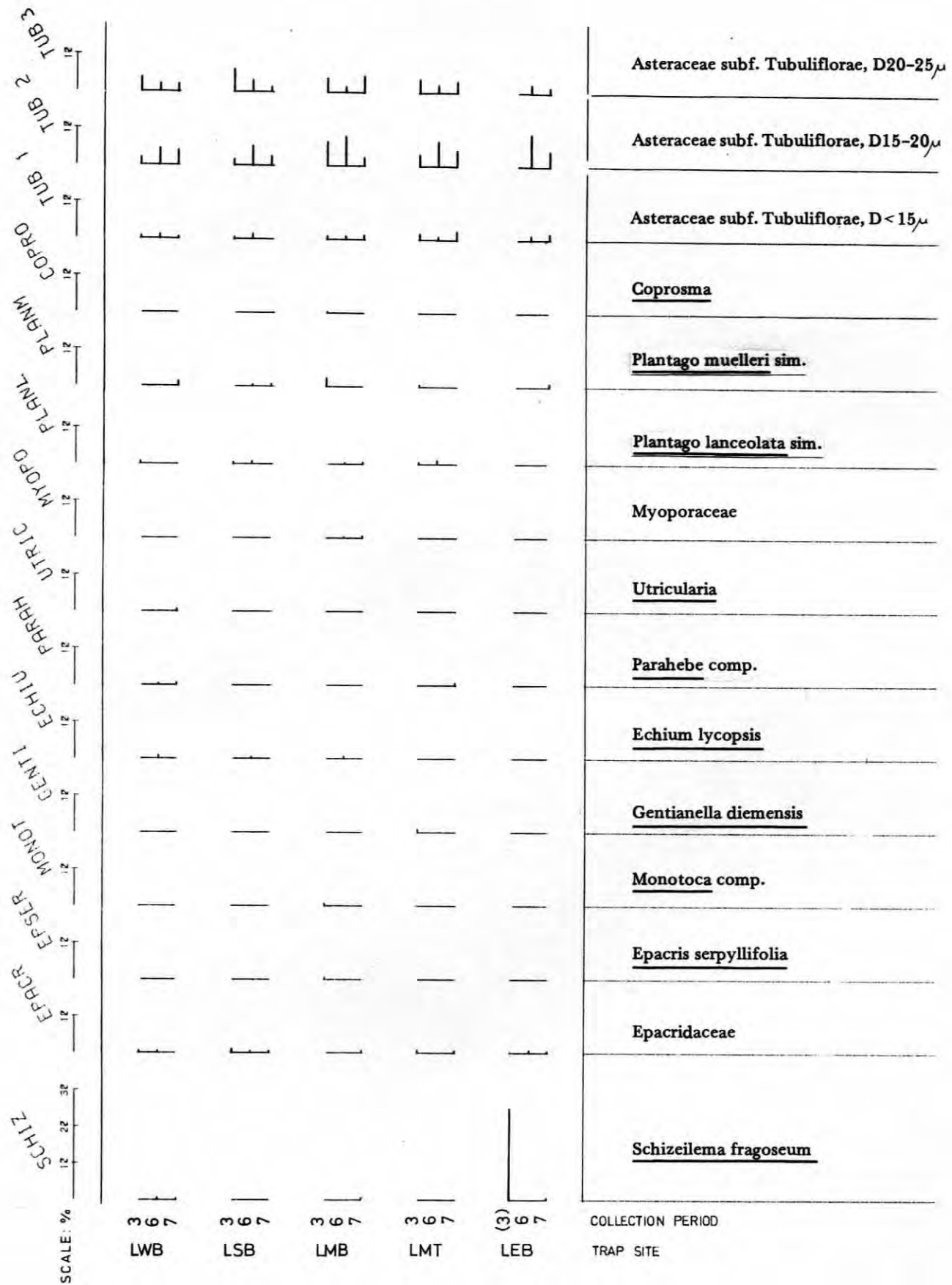


FIG. 4.12 LAKE SEDIMENT TRAPS RPF DIAGRAM (continuation 3)

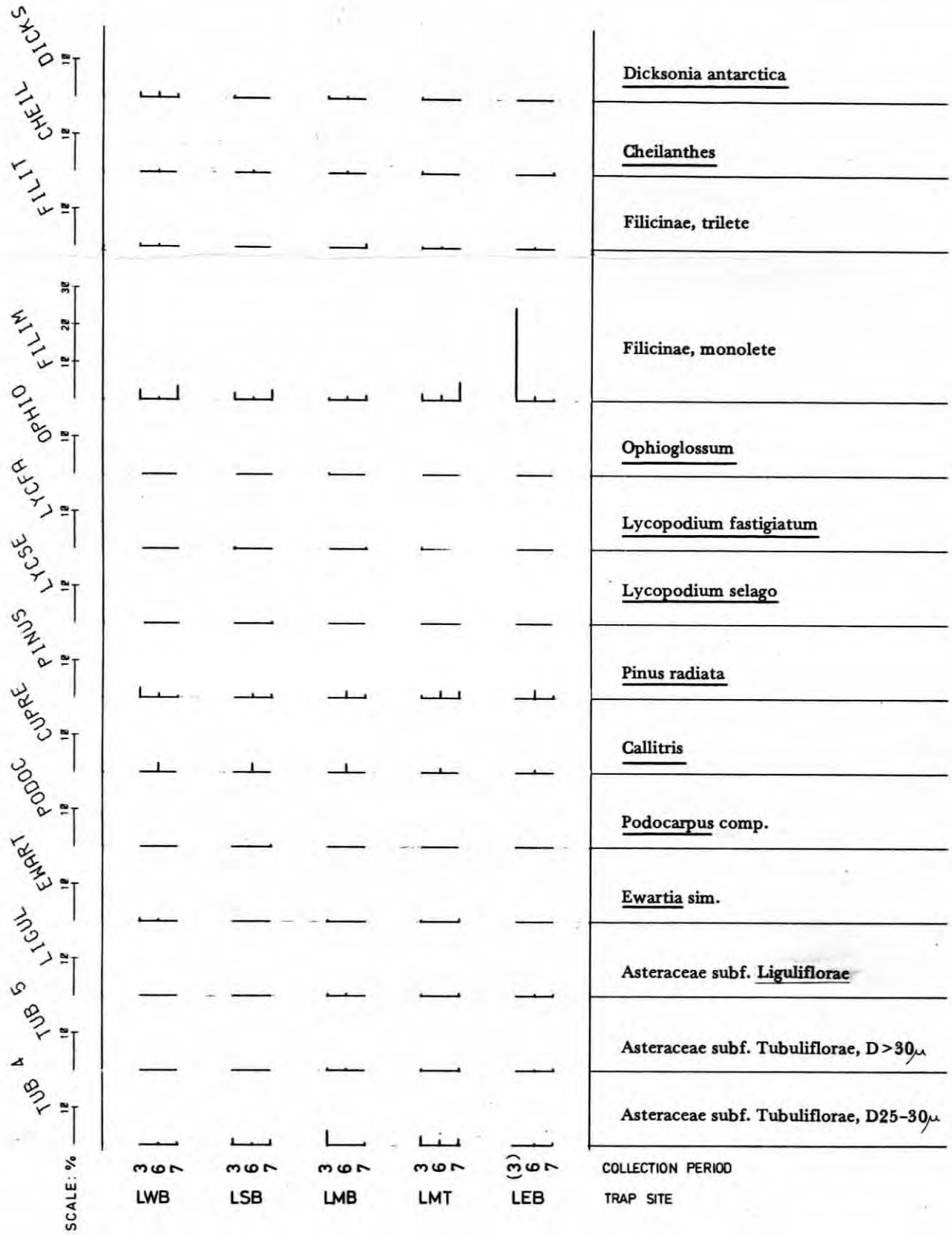


FIG. 4.12 LAKE SEDIMENT TRAPS RPF DIAGRAM (continuation 4)

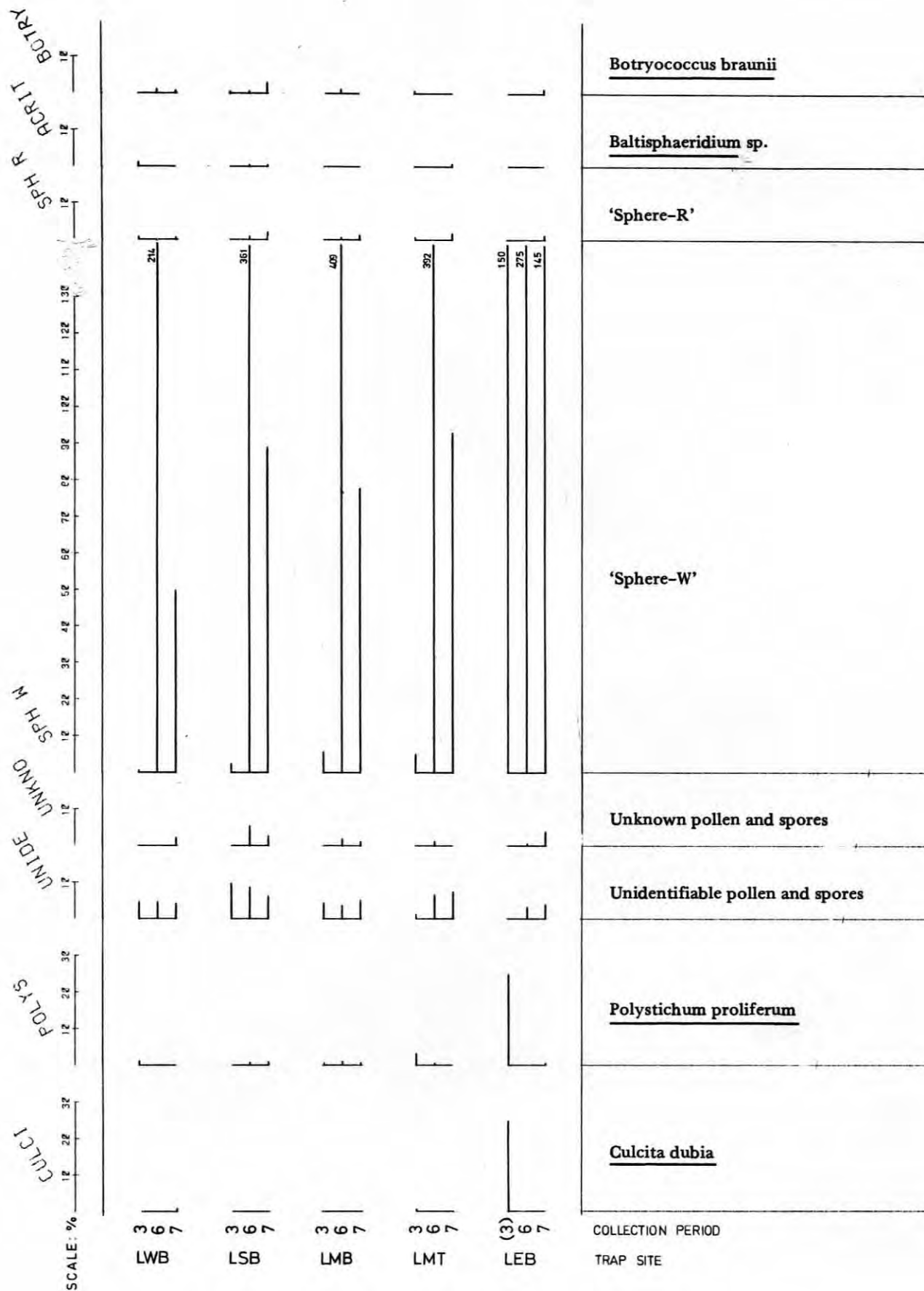


FIG. 4.12 LAKE SEDIMENT TRAPS RPF DIAGRAM (continuation 5)

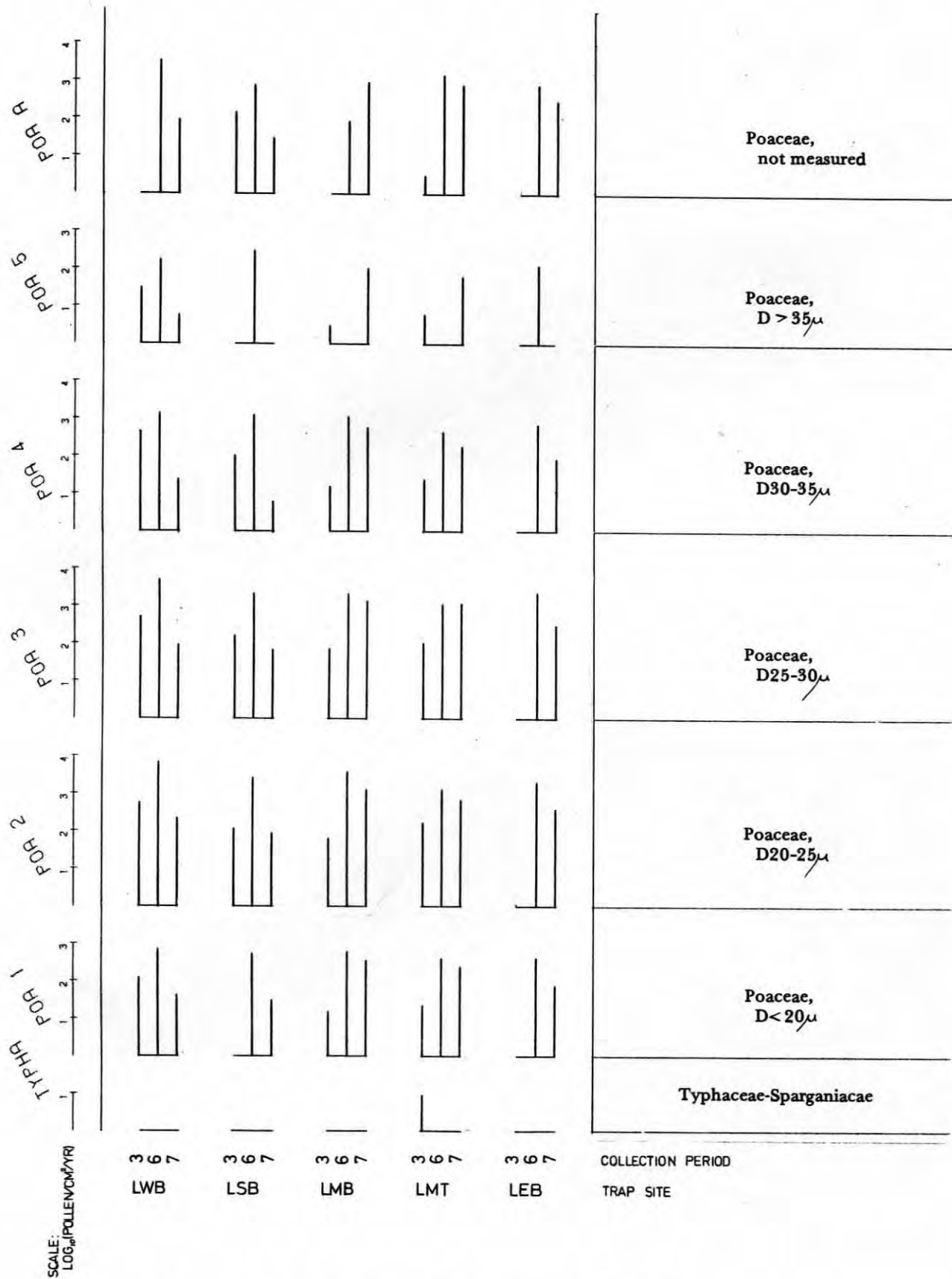


FIG. 4.13 LAKE SEDIMENT TRAPS PDR DIAGRAM

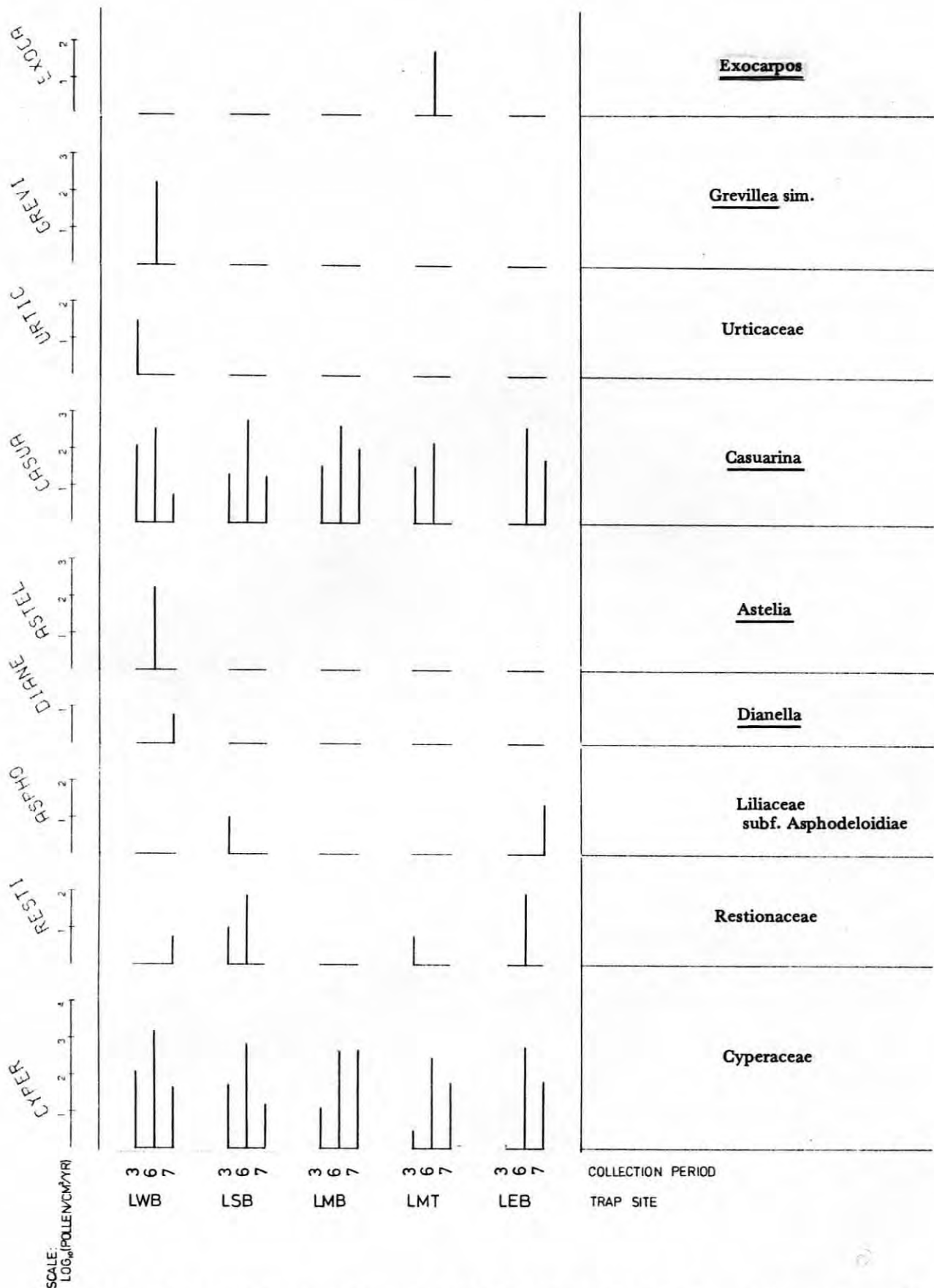


FIG. 4.13. LAKE SEDIMENT TRAPS PDR DIAGRAM (continuation 1)

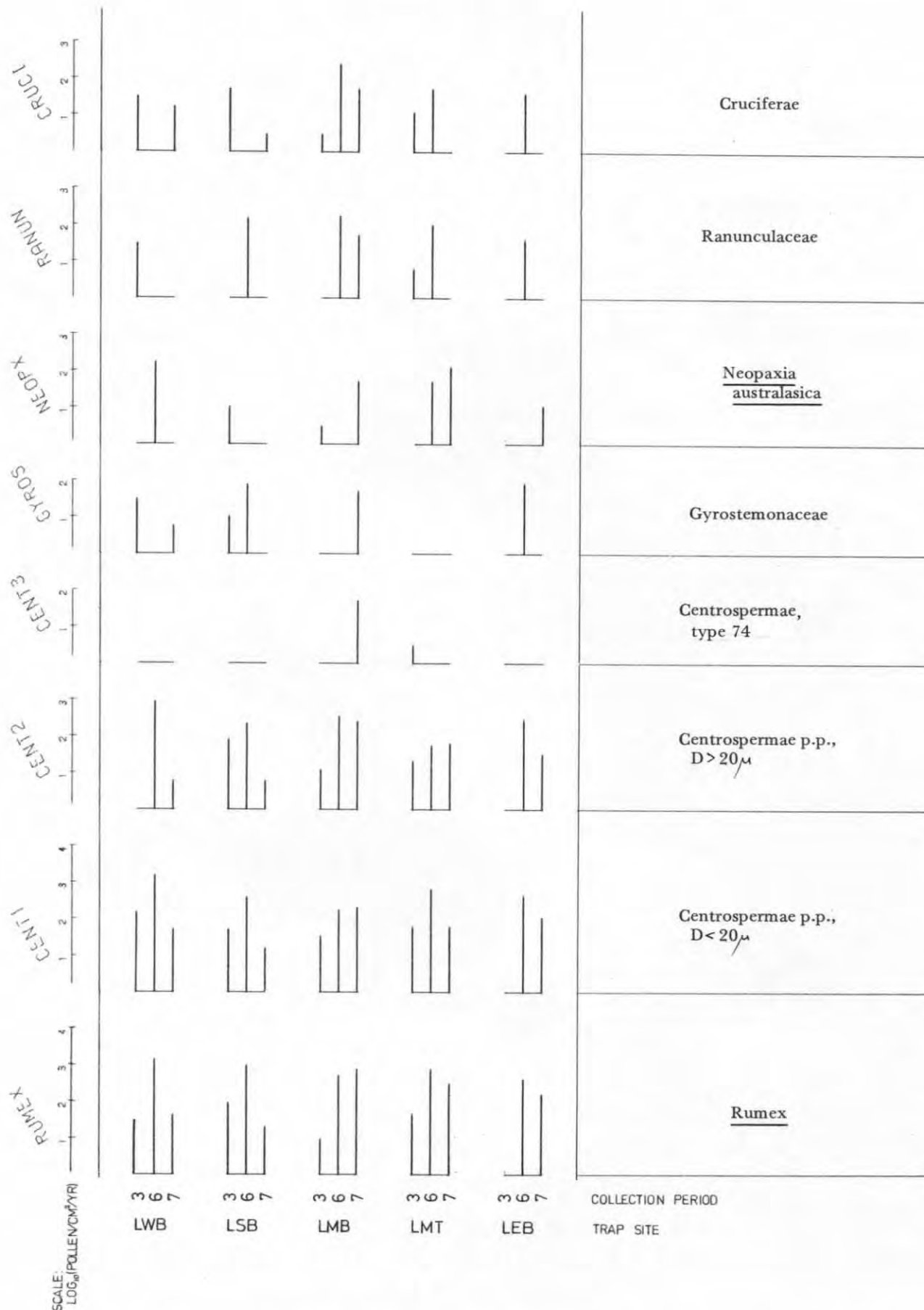


FIG. 4.13 LAKE SEDIMENT TRAPS PDR DIAGRAM (continuation 2)

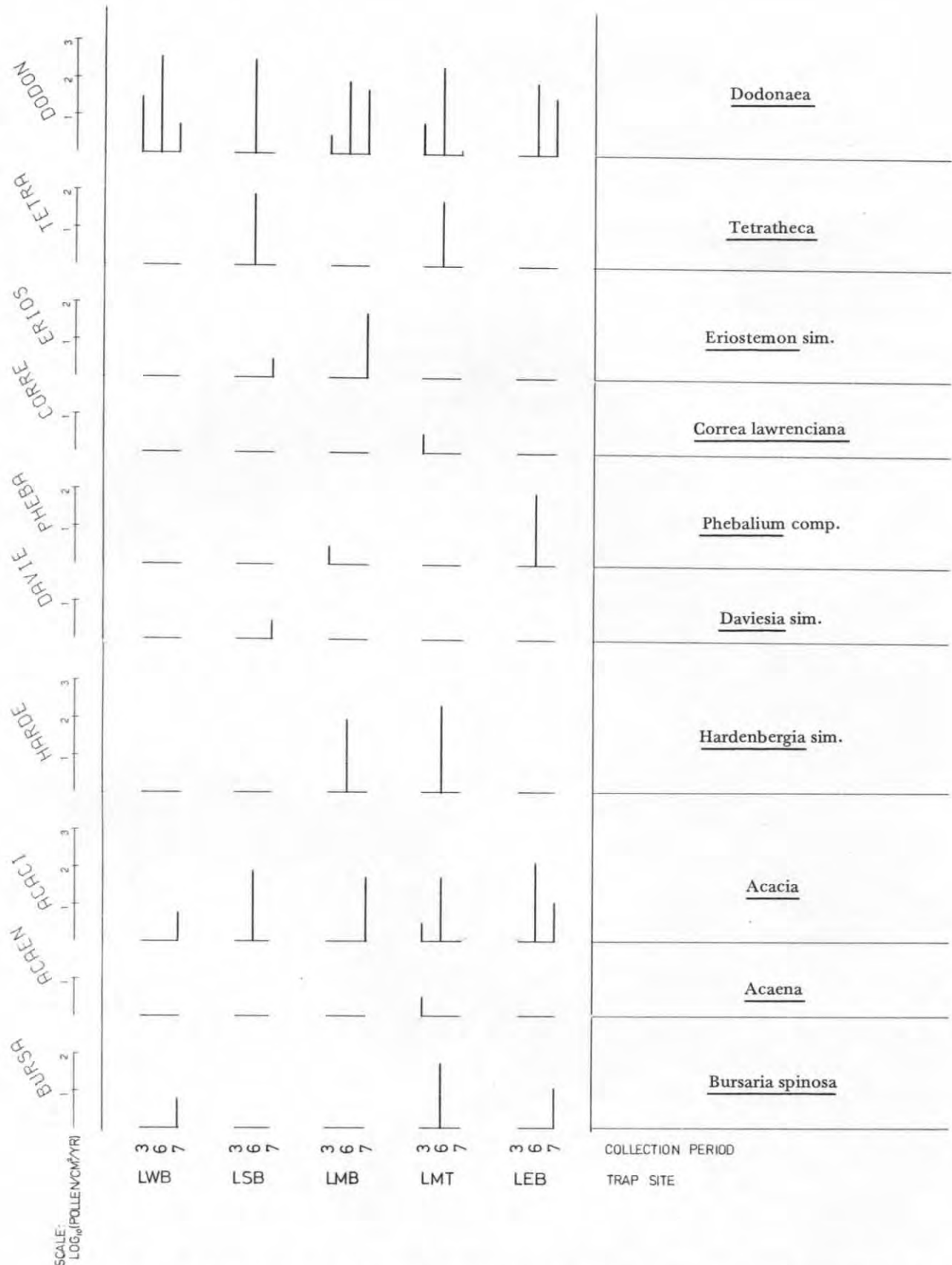


FIG. 4.13 LAKE SEDIMENT TRAPS PDR DIAGRAM (continuation 3)

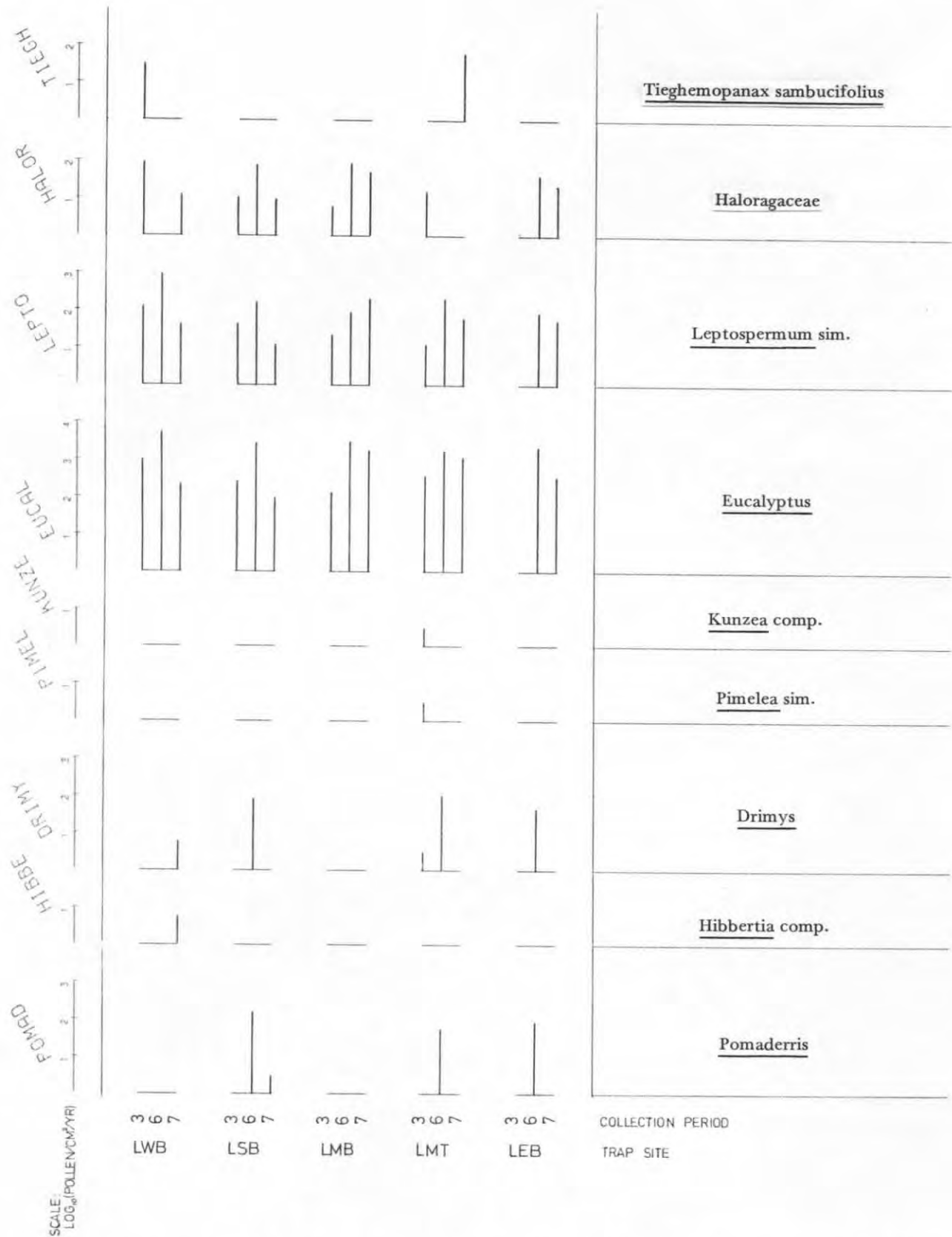


FIG. 4.13 LAKE SEDIMENT TRAPS PDR DIAGRAM (continuation 4)

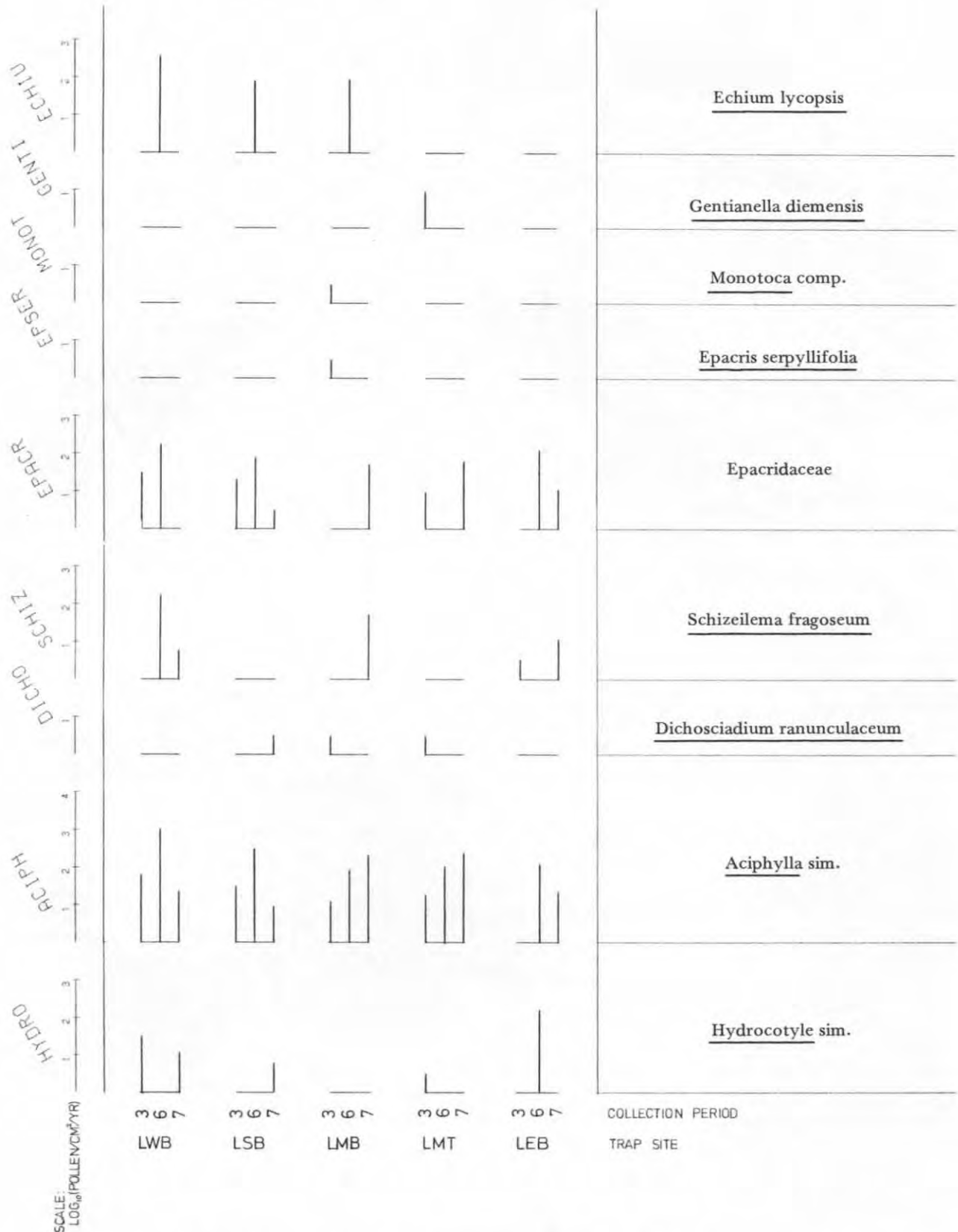


FIG. 4.13 LAKE SEDIMENT TRAPS PDR DIAGRAM (continuation 5)

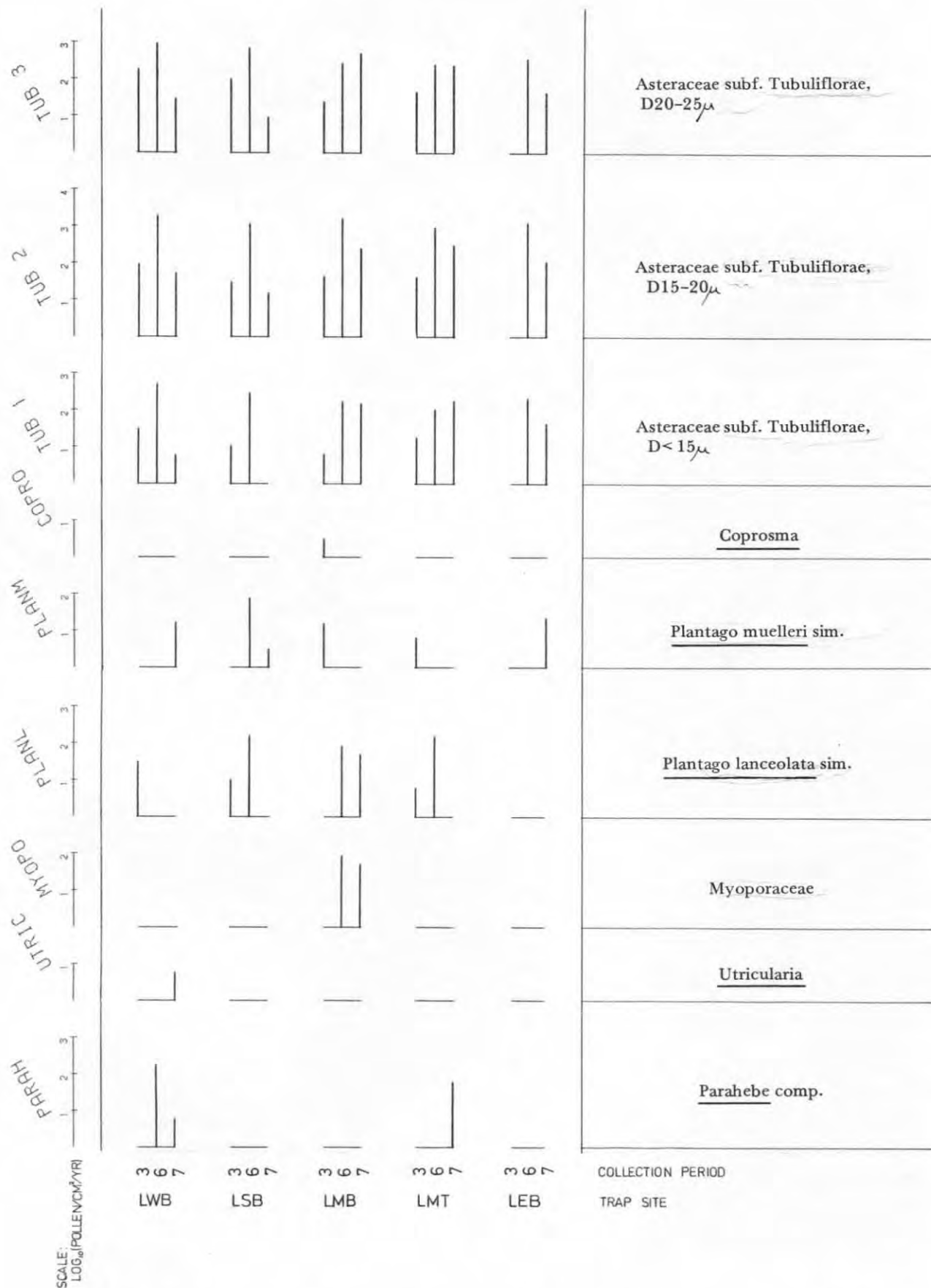


FIG. 4.13 LAKE SEDIMENT TRAPS PDR DIAGRAM (continuation 6)

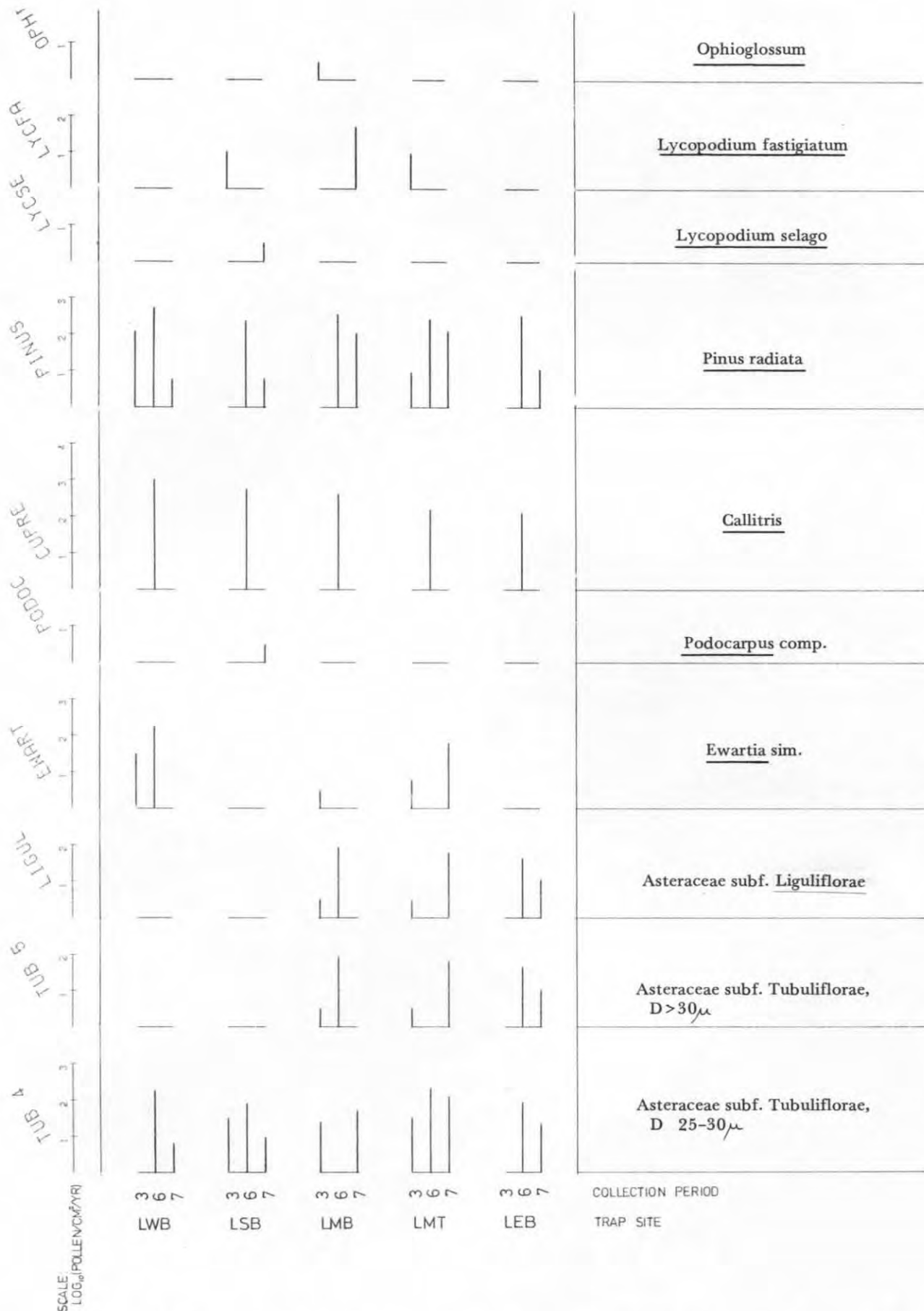


FIG. 4.13 LAKE SEDIMENT TRAPS PDR DIAGRAM (continuation 7)

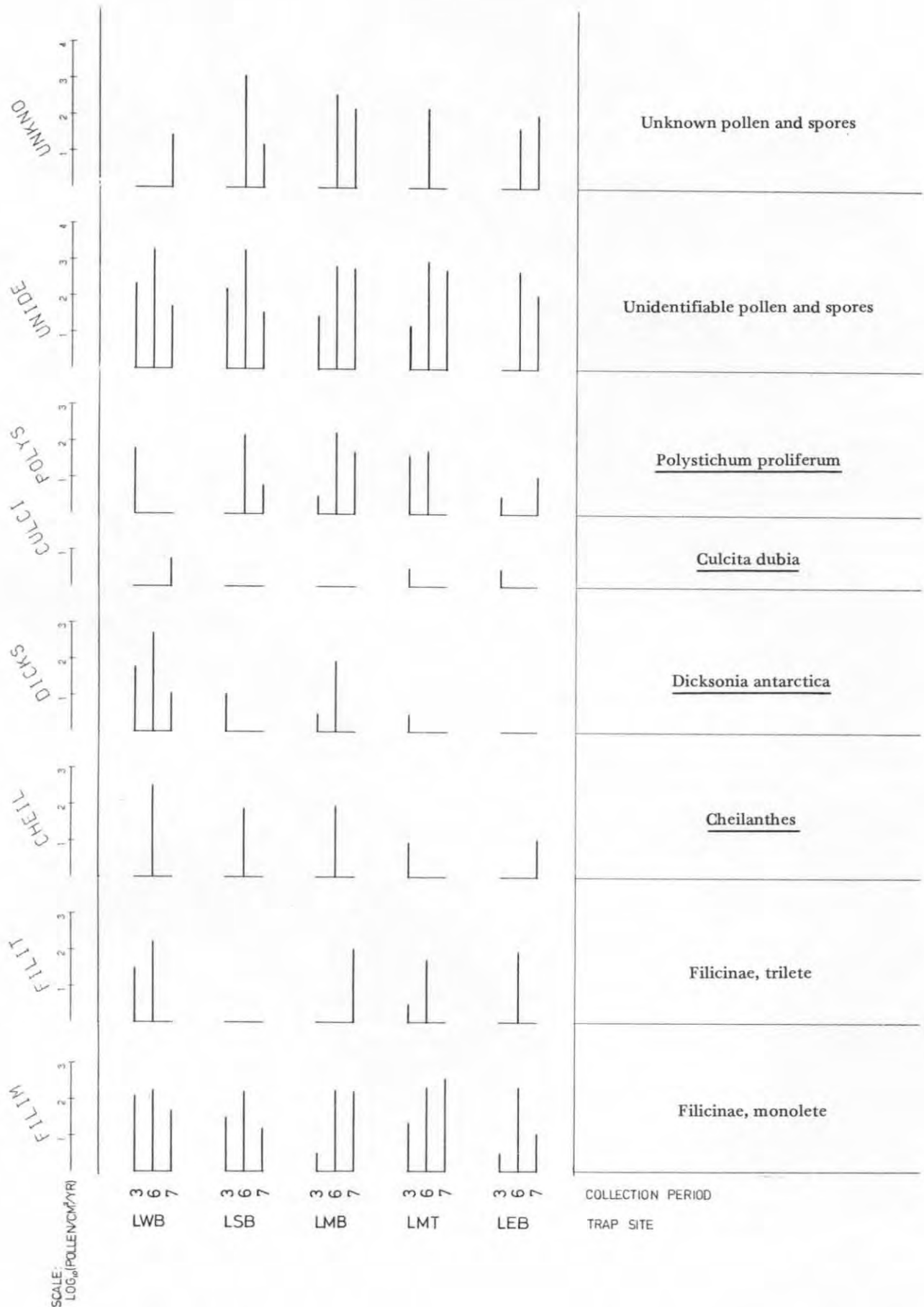


FIG. 4.13 LAKE SEDIMENT TRAPS PDR DIAGRAM (continuation 8)

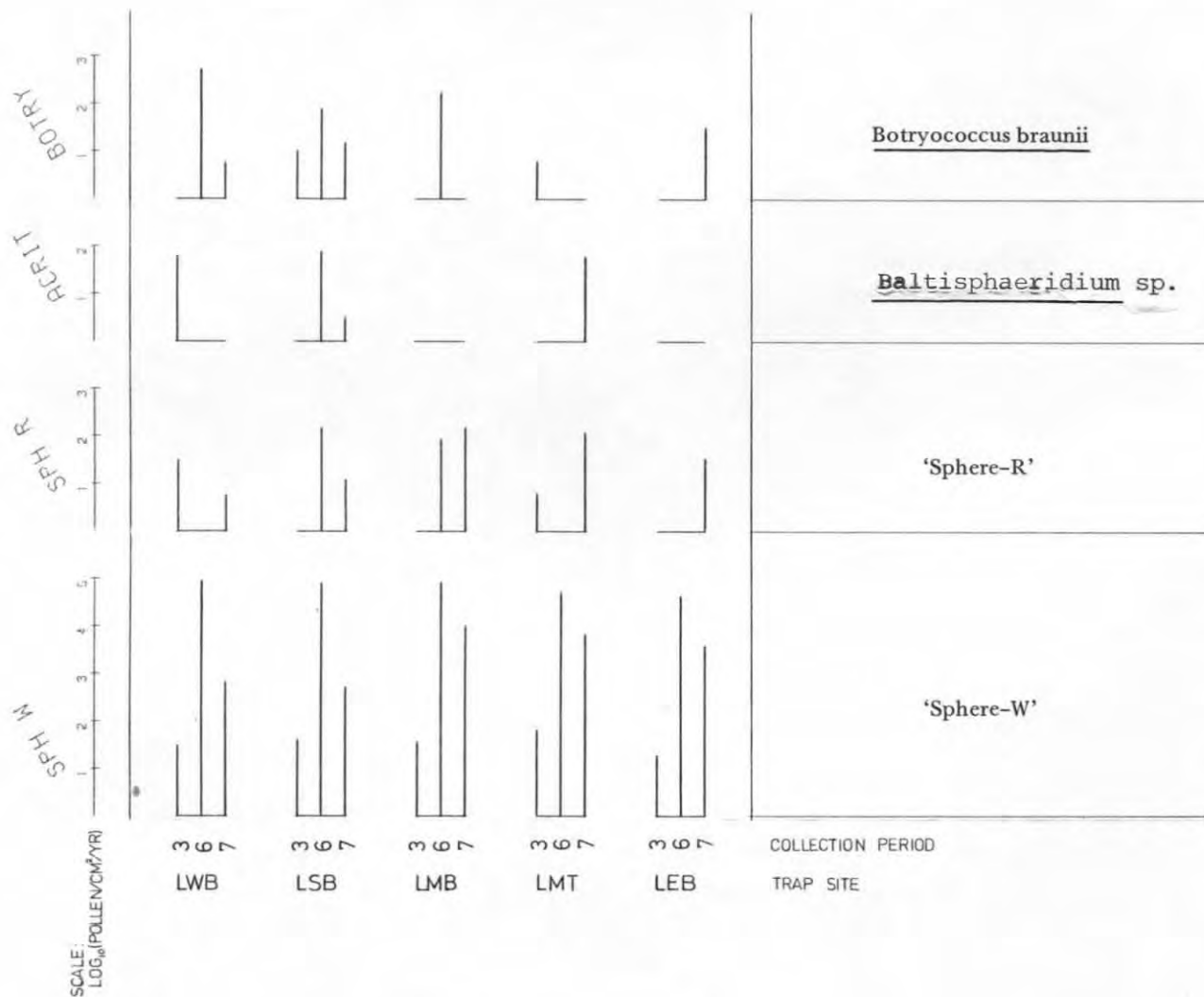


FIG. 4.13 LAKE SEDIMENT TRAPS PDR DIAGRAM (continuation 9)

ii) Deposition of pollen near a stream or surface wash source, or refloated by wind from shore vegetation. The remarks in i) apply if the spectrum of the contributing pollen is greatly different from that deposited in the central part of the lake, from other sources. If the incoming pollen is similar in relative proportions of taxa, the effect would be distinguishable only in greater total PDR near such sources.

Contribution of pollen transported as suspended load in the major influent stream, at the south-western corner of the lake, could explain the high relative PDR observed in each period at the LWB site. It is unfortunate in this regard that a trap period did not coincide with a period of low flow in the stream: as will be shown later, stream pollen influx is low at such times.

iii) Deposition of pollen in areas of relatively still air, on the water surface.

This possibility is excluded by comparison of aerial pollen trap deposition rates at the Delta and Efflux sites, and is also unlikely theoretically, so long as pollen is not appreciably refloated from the ground, for the reasons given in the discussion on aerial pollen trap performance in Chapter 2.

iv) Differential deposition of pollen grains according to their settling velocity in water.

This effect has been described by Davis (1973). Pollen grains with rapid settling are deposited evenly onto the sediment throughout the lake. Those with slower settling due to smaller size or lower density, are kept in suspension in the turbulent water of the epilimnion, while being transported shorewards by wind-driven water currents. Deposition occurs where these currents lose velocity or turn downwards, near the shoreline. Davis reports ratios of ragweed pollen (diameter 18μ , settling velocity perhaps 18 cm/hr.) to oak pollen (diameter 28μ , settling velocity perhaps 25 cm/hr.) of up to 4:1 from this effect.

Comparison of relative pollen frequencies of major taxa (Poaceae, Eucalyptus, Asteraceae) fails to reveal any differences of this magnitude. Indeed, RPF of Asteraceae ($D < 20\mu$), is highest in the deep lake sediment trap, LMB, in the first summer period, while that of the probably more rapidly settling Poaceae ($D > 30\mu$) is higher in the nearer-shore traps

LWB and LSB. The relative frequencies of other taxa are too low for significant trends to be seen. Thus no evidence of the effect has been observed. Possible reasons for this are masking of the effect by other processes, or that the sediment traps were too deep in the lake to discover the effect. The latter would not seem to apply, as traps LWB and LMT were located in the epilimnion, unless pollen is confined to very close to the lake surface.

v) Movement (redeposition) of sediment from one part of the lake bed to another. This is discussed under 'THE POLLEN BUDGET' below.

vi) Loss of pollen (perhaps preferentially) by transport from the lake in outflowing water, or by reflation by wind from the lake surface.

Loss in outflowing water is discussed under 'THE POLLEN BUDGET'. Reflation of pollen from a water surface has been experimentally established by Valencia (1967), and was invoked by Rowley and Walch (1972) to explain appearance in isolated ponds of exotic pollen introduced by a nearby stream.

A good test for this effect would seem to be the presence or absence of the lacustrine organism 'Sphere-W' in the Efflux aerial pollen traps. Despite high frequencies of this type in lake sediments and sediment traps, not a single grain was observed in collections from the aerial pollen traps. It is concluded that the effect is negligible, or that appreciable reflation is confined to within 3 m of the lake surface (below the level of the pollen traps).

Summary

Differential sedimentation of pollen grains of different taxa does not appear to be important in the lake below 5 m depth at the present time. It may remain undetected in the less frequent taxa and may be obscured by other processes. Loss of pollen by reflation from the lake water surface does not seem to be significant.

STREAM WATER SAMPLES

Stream water samples were collected on five occasions. On one of these the efflux was ice-covered, preventing sampling. A further sample was lost, leaving only eight samples. This is unsatisfactory, but some observations can be made. Sample collection and processing is described in Chapter 2. Results of pollen counts may be found in Appendix D, Table D.9.

Stream flow was gauged at sampling times with either a velocity head rod (Linsley, Kohler and Paulhus, 1949, p. 202) or an Ott propellor type meter. Observations of flow velocity were made at several points in a regular cross-section of the stream, and the total flow obtained by integration over the cross-sectional area. The resulting measurements are probably within 30% of the true flow.

Measurements on 20.1.72 suggest that in a period of moderate stream flow, the major influent stream contributes about half of the lake effluent water, while other streams contribute about one quarter. The remainder appears to be provided by seepages and soil moisture flow. Continuous records of stream depth were made by Sumner chart recorders with pneumatic sensors (C.S.I.R.O.1967) installed on the sampled streams. These show that stream is very low and steady during the period of snow cover, from June to October. Spring thaw, often accompanied by rain, results in the highest observed stream levels. During early summer, stream flow follows a diurnal pattern, with higher flow during the snow-melt period in the afternoon, except when increased by rainfall. Flow decreases through late summer and autumn, reaching winter levels in May. This pattern is in accord with the observations of Costin et al. (1961) that while the Snowy River catchment above Guthega receives about 30% of its annual precipitation during the spring thaw period, the catchment produces more than 50% of its water yield in this period.

Typical rates of flow are (in l/sec.):

	Influx sampling stream	Efflux
winter	30	100
snow melt period	500	2000
late summer	100	200

Calibration of stream stage in terms of flow did not extend to flood levels. The maximum observed depths, observed during

the snow-melt period, correspond to flows of the order of magnitude of 2000 l/sec and 8000 l/sec in the influent and effluent streams respectively.

Magnitude of pollen flux

Part of table D.9 is repeated below. Pollen flux refers to the product of pollen concentration in the water and stream flow: that is, the total amount of pollen being imported into or exported from the lake by these streams in one second.

	Date	Pollen Concentration (grains/l)	Stream Flow (l/sec)	Pollen flux (grains/sec)
Influx Stream 1	21.1.71	298	180	54000
" "	2 2.7.71	54	30	1600
" "	3 18.11.71	30	1000	30000
" "	5 1.6.72	128	30	3800
Efflux Stream 1	21.1.71	292	40	11700
" "	3 18.11.71	9	>2000	>18000
" "	4 20.1.72	532	400	213000
" "	5 2.6.72	650	90	59000

Influent stream water pollen concentration is highest in late summer, during a period of above average flow. Despite the high flow on 18.11.71, pollen concentration was low, resulting in a lower rate of pollen flux than at the summer sampling time. Combination of medium levels of pollen concentration with low flow rates in the two early winter samples resulted in relatively low pollen flux.

Several authors (Traverse and Ginsberg, 1966; Groot, 1966; Peck, 1973) have shown that there is a close correlation between pollen and suspended mineral sediment concentrations in water. For a moorland catchment in England, Peck showed that both pollen and total suspended sediment concentration increased with stream discharge. Crowder and Cuddy (1973) have shown, however, that net pollen concentration in a creek flowing through woodland in Canada varied independently of water flow, although suspended sediment load was closely correlated with discharge. From these studies it is clear that the nature of the pollen supply to the stream is critical in determining the

relationship of concentration to discharge. If pollen is derived in the same way as other sedimentary particles, as appears to be the case in the catchment studied by Peck, supply will closely correlate with runoff, which depends on rainfall character, soil erodibility, ground slope, and plant cover (Smith and Wishmeir, 1962). Pollen concentration at the ground surface, which varies seasonally, as do the above factors, will also be important. Crowder and Cuddy attributed the bulk of pollen transported in the stream in their study area to direct sedimentation of airborne pollen onto the stream surface, although a background component, probably due to soil erosion, could be demonstrated.

Sediment yield from experimental plots in the alpine area of the Snowy Mountains has been studied by Costin and co-workers (1960). Sediment yield was greatest from plots with a minimal vegetation cover, especially during summer storms when the soil surface was initially dry and less permeable. This points to an explanation for the apparently greater pollen concentration in the summer stream sample than in the spring thaw one. Sediment yield could be expected to be greater in summer, for a given runoff. In addition, pollen concentration at the soil surface would increase to higher levels in summer than in spring, when continual flushing by snow meltwater would occur; local pollen production would also be higher in summer.

Efflux stream water pollen concentration was high in the summer samples and low in the spring one, in accord with higher aerial pollen influx and less water flushing in the summer. The winter sample, however, has the highest concentration of any measured. This may be due to reflation of lake sediment during the autumn isothermal mixing of lake water. The period of mixing in 1972 is unfortunately unknown, but may have been rather late. The pollen concentration of the second summer sample is higher than in the first summer sample, in accord with the greater rate of aerial pollen deposition observed in that year.

As with the influent stream samples, the maximum observed pollen flux was associated with neither maximum pollen concentration nor maximum stream flow, but with moderate values of both. Since the surface area of Blue Lake is approximately 155100 m^2 , this pollen export represents about 4330 grains per square centimetre of lake surface per year (1000 grains/sec represents $20.34 \text{ grains/cm}^2 \cdot \text{yr}$). The relevance of this and more

typical figures will be considered in 'THE POLLEN BUDGET'.

Nature of the stream transported pollen

Sample pollen percentages are compared in Table 4.1 with the percentages in lake sediment traps. These latter were obtained by averaging the percentage figures for the five traps, after combining the deposition figures for the later two trap periods (essentially one year's record).

Relative pollen frequencies of most taxa are too erratic among the stream samples (partly because of the low pollen counts) to draw very definite conclusions, but it may be noticed that Cyperaceae RPF is higher in the Influx Stream samples than in either Efflux Stream or sediment trap samples. This is consonant with the high proportion of fen vegetation near the stream source in Upper Blue Lake Cirque. Other frequencies are of the same order as the sediment frequencies, but variation is great enough to suggest a variable source.

Efflux stream RPF features include higher Eucalyptus than in the lake sediment, and generally lower Poaceae. Selective removal of Eucalyptus pollen from the lake may result from removal of surface water relatively rich in this pollen type. Possible reasons for such enrichment are unknown: the highest RPF is observed in sample EFF5, taken after the Eucalyptus flowering season had ceased. Smaller pollen types, such as Asteraceae ($D < 20\mu$) do not seem to have appreciably higher frequencies in the Efflux stream samples, so that simple settling rate fractionation of pollen in the lake surface water does not seem to be an explanation.

Table 4.1 RPF in Stream Water Samples

Pollen Taxon	Influx Stream				Efflux Stream				Modern Lake Sediment*
	1	2	3	5	1	3	4	5	
Poaceae	26†	15	39	18	39		20	19	41.2
Cyperaceae	13	4	31		3		6		3.1
<u>Casuarina</u>	1			1			1	3	1.9
<u>Rumex</u>	2	4		15	7		7	2	4.0
Centrospermae (D<20μ)	2	8			1		2	1	2.8
<u>Pomaderris</u>							1	4	0.3
<u>Eucalyptus</u>	8	8		12	18		21	55	13.5
<u>Leptospermum</u> sim.	1	4		2	1		4		1.1
Haloragaceae					1		1	4	0.2
<u>Aciphylla</u> sim.	4				1		2	1	1.3
Epacridaceae	1						1	1	0.3
Asteraceae (D<20μ)	8		8	8	10		10	8	7.7
Asteraceae (D20-30μ)	3			7	5		7	1	3.0
Ast. Liguliflorae					1		1	1	0.2
<u>Pinus</u>	4		8	5			2		1.6
Total <u>Lycopodium</u>	1				1	25			.01
Total Filicinae			8		1		2	1	2.5
'Sphere-W'					4		79	7	308
Pollen Count	144	26	13	62	77	4	199	286	

* Mean of lake sediment trap % figures for combined trapping periods 6 & 7.

Percentage figures.

THE POLLEN BUDGETPollen influx - typical measurements

i) Alpine Aerial Pollen Traps

Pollen deposition figures for the alpine pollen traps were (in grains/cm²) :

	1970-71	1971-72
SUM	560	1520
COL	440	1790
DEL	730	4850
EFO	530	1680
EFR	550	1750
HED	320	1590

Since 1970-71 figures for the DEL, EFR and HED traps were not based on a full season's trapping, a typical figure for this season is probably about 600 grains/cm². In 1971-72 the DEL trap had a high proportion of insect-contributed Wahlenbergia pollen, and a typical figure for this season is about 1800 grains/cm².

ii) Snow Cores

From earlier in this Chapter typical pollen deposition figures for the 1970 and 1971 snow seasons were 560 and 1600 grains/cm² respectively.

iii) Influent Streams

Using a typical late summer stream flow of 100 l/sec and pollen concentration of 200 grains/litre, pollen influx would be 20000 grains/sec, or about 400 grains per square centimetre of lake surface per year. If the maximum observed rate of pollen influx were used instead, the pollen influx would be 1100 grains/cm²/yr. Unless pollen flux in peak flows is much greater than the samples suggest, these are maximum estimates for this stream, as pollen flux would generally be lower.

Total pollen influx estimate

By summary i) and ii) above, the following figures for direct pollen deposition on the lake surface are obtained :

1970-71	1160 grains/cm ²
1971-72	3400 "

Addition of the influent stream pollen influx would raise these figures by possibly 1000 grains/cm².

Comparison of lake sediment trap gross pollen deposition rates.

Annual total deposition rates, obtained by summing the deposition figures for periods 6 and 7 are :

Trap depth		
6 m	LWB	34130 grains/cm ² /year
10 m	LSB	16440 "
19 m	LMB	16450 "
5 m	LMT	11440 "
12 m	LEB	12000 "

(the period is not exactly one year, but will suffice for present purposes).

The magnitude of the sediment trap deposition rates appears to be related to position relative to a northwest-southeast axis through the lake, rather than to trap depth. A possible explanation for this is that influent stream provides the bulk of the pollen, which is deposited soon after its entry into the lake. This would appear to be excluded by the magnitude of the stream influx figures (above).

The magnitude of the LMT trap catch indicates that a good deal of the pollen caught in lower traps circulates through the upper waters of the lake. Comparison of apparent deposition rates in the traps for the three collection periods (see Figure 4.13 and Appendix D, Table D. 8) shows that the vast bulk of pollen was deposited between early winter and mid-summer, and that apparent deposition rate was much higher during this period. Deposition rates during the two summer-autumn periods were of similar magnitude to aerial pollen trap rates during these periods.

The magnitude of snow melt plus early summer aerial pollen deposition is insufficient to explain this discrepancy. It is concluded that significant redeposition of sediment occurs during periods of lake water mixing in autumn and spring, as described by Davis (1973). Support is lent to this by the high pollen concentration observed in efflux stream water on 2/6/72, although as noted, this may be slightly later than the mixing period.

The greater deposition in trap LWB, in all trap periods, is still unexplained. Since overturn of the lake water is not involved in the last period, some other factor seems to be indicated. One possible explanation is stirring of the lake bottom sediments by the influent streams at the head of the lake, resulting in greater suspended sediment there. A pollen deposition rate estimate for core 7 could possibly settle this problem.

Comparison of recent PDR from sediment core 1 with sediment trap rates.

From Chapter 3, recent total PDR has been about 25000 grains/cm²/yr. Concentration in the surface sediment sample (LMD 1) is approximately 406000 grains/cc while that in the two highest samples of core 1 is 416000 and 490000 grains/cc. These show a slight decrease in concentration with decreasing depth, but the difference is probably not significant. It is possible that pollen deposition rate has declined since the mean date represented by the surface mud sample, but in view of the relatively small degree of vegetation disturbance, this seems unlikely to be due to great change in pollen influx. Consequently, the annual PDR observed for the LMB trap, closest to the core site, of 16450 grains/cm²/yr., is a problem if most of this apparent deposition is due to pollen resuspended from the sediment. Higher trap catch than net annual deposition would be expected.

One possible explanation is that the buoys suspending the sediment traps intercepted a good deal of sediment. Some sediment deposit was indeed noted, but not of comparable

amount to that caught in the traps. A correction, however, must be applied to the core estimate of pollen deposition to allow for uneven deposition over the lake bottom. As has been observed, there is little sediment at water depths of less than about 12 m. Cores 1-3, 6, 7 and 8 showed that the thickness of sedimentation unit A varied somewhat from core to core, but that a reasonable estimate of its mean thickness over the lake floor between these cores would be 4 m. If pollen is deposited in the same way as the bulk of the fine sediment (Peck 1973), then a more reasonable estimate of mean pollen deposition per unit area of lake surface could be obtained by first computing the mean rate expected over the area with water depth greater than 12 m, then correcting this rate to an estimate based on the total lake area. Using the figures of 155100 m^2 for the total lake surface area, 86350 m^2 for the area with water depth greater than 12 m, 5.2 m for the thickness of unit A in cores 1-3, and $25000 \text{ grains/cm}^2/\text{yr.}$ for recent pollen deposit rate in these cores, a corrected figure of $10700 \text{ grains/cm}^2/\text{yr.}$ is obtained.

This estimate is less than the observed catch in traps LWB, LSB and LMB and is of the same order as the catch in traps LMT and LEB. This supports the case for redeposition of sediment.

Pollen influx to Blue Lake has been estimated, above, at between 2000 and $4500 \text{ grains/cm}^2/\text{yr.}$ (rounded figures for years 1970-71 and 1971-72).

Pollen deposited in lake sediments, plus that destroyed by mechanical or faunal action before final deposition, plus loss in the efflux stream should equal the pollen influx. The mean deposition rate for lake sediments has been calculated above at $10700 \text{ grains/cm}^2/\text{yr.}$ No estimate is available of the quantity destroyed.

The maximum observed rate of pollen export from the lake was $4330 \text{ grains/cm}^2/\text{yr.}$ Using more typical figures of 200 l/sec stream flow and 500 grains/litre pollen concentration, rate of pollen export would be $2030 \text{ grains/cm}^2/\text{yr.}$ This is still notably greater than the influx

stream typical figure.

There is thus a problem in balancing the budget, on the available estimates, since the maximum estimate of pollen influx is 4500 grains/cm²/yr. while pollen deposition plus export is about 13000 grains/cm²/yr.

In her study of small lake catchments of Yorkshire mentioned previously, Peck (1973) was also unable to reconcile pollen deposition figures obtained from Tauber trap catches with higher rates of pollen deposition observed in short sediment cores, although no correction for sediment redistribution, as above, was made. The discrepancy varied with pollen type : typical values of the aerial deposition component as a percentage of the sediment core rates were 13-4%. Peck considered that most pollen in the reservoir sediments was contributed by inflowing streams, support for this argument being the close comparison of stream sediment trap and lake core pollen spectra. A poor correspondence was noted between the lake core and aerial pollen trap spectra.

In the present study, stream samples are not suitable for comparison (but see earlier, this Chapter). Time was not available for a detailed comparison of the mean pollen spectra of the various types of samples, but percentage figures for some important taxa are listed below.

Snow Core results are the average of 1971 core percentages, alpine Tauber trap results the average of 1971-72 season totals, lake sediment trap results the average of trap periods 6 and 7 (1971-72).

Attention is drawn to the percentage values for Cyperaceae, Leptospermum sim. (which includes Baeckaea), Aciphylla sim. and total Filicinae. These are all lower in the snow core and Tauber trap results than in the lake sediment samples. These are taxa which could be expected to be significantly associated with stream pollen transport, because of their preferred paludal or riparian habitats.

Centrospermae ($D < 20\mu$), Asteraceae ($D < 20\mu$) and Pinus have high RPF in the snow cores, confirming their origin as extra-alpine. Poaceae and Eucalyptus have relatively low values, which do not appear to be compensated for by high alpine trap values. This may be due to variation in pollen production between years, the sediment trap and Lake Surface Mud Spectra being smoothed by the effects of sediment reflation.

Comparison of Snow Core (A), Alpine Tauber Trap (B), Lake Sediment Trap (C) and Lake Surface Mud Pollen Spectra (all % figures).

	A	B	C	D
Poaceae	19.4	32.4	41.2	33.2
Cyperaceae	0.8	0.9	3.1	4.2
<u>Casuarina</u>	1.4	0.4	1.9	0.8
<u>Rumex</u>	4.4	9.1	4.0	1.3
Centrospermae ($D < 20\mu$)	6.8	2.3	2.8	1.8
<u>Pomaderris</u>	0.2	0.5	0.3	0
<u>Eucalyptus</u>	7.5	10.5	13.5	15.7
<u>Leptospermum</u> sim.	0.3	0.7	1.1	1.3
Haloragaceae	1.0	0.4	0.2	0.8
<u>Aciphylla</u> sim.	0.2	0.2	1.3	2.6
Epacridaceae	0.02	0.4	0.3	0
Asteraceae ($D < 20\mu$)	23.8	0.8	7.7	8.9
Asteraceae ($D 20-30\mu$)	6.8	7.9	3.0	7.5
Liguliflorae	0.2	0.7	0.2	0
<u>Pinus</u>	8.3	0.5	1.6	0.3
Total Filicinae	0.2	0.5	2.5	3.7
'Sphere-W'	-	-	308	50.9

Regarding the snow core and alpine Tauber trap results as good estimates of the direct aerial input into Blue Lake, a minimum estimate of stream pollen input is obtained by subtracting their sum from the corrected sediment core pollen deposition rate of $10700 \text{ grains/cm}^2/\text{yr}$. The resulting value is $7300-9500 \text{ grains/cm}^2/\text{yr}$, or 68-89% of the net pollen deposition rate. This is higher than any observed stream pollen flux, and would

imply very high efficiency of pollen erosion from the stream catchment, since Blue Lake represents 7.1% of the area of its catchment. It is possible that flood peak flows are of great importance, but there remains the problem that observed stream pollen export rates were higher than import rates.

An explanation for the lack of convincing balance may lie in unexpectedly low Tauber trap efficiency. This is obviously a problem for the future.

CHAPTER 5

CONCLUSIONSTHE POLLEN BUDGET STUDY

The best estimates of the total annual pollen and spore input to Blue Lake that were obtained were :

Direct input to lake surface

snow cover 560-1600 grains/cm²/yr.

water surface 600-1800 grains/cm²/yr.

Stream Input

400 grains/cm²/yr.

A balance with the sum of stream export and mean pollen deposition estimated from cores was not achieved.

These values were :

Stream Export 2030 grains/cm²/yr.

Mean pollen deposition over area of lake 10700 grains/cm²/yr.

Possible reasons for this lack of balance have been discussed. Either stream import and export is very much higher than seems likely, or the Tauber pollen traps did not catch pollen as efficiently as the lake surface. Since it seems likely from Geehi Valley pollen trap data that pollen production is much greater during summer, while alpine Tauber trap catch was not appreciably greater than that caught by the winter-spring snow surface, the latter explanation is favoured.

Reflotation of pollen from the lake surface was shown not to be significant. Reflotation of lake sediment in autumn and spring seems likely. The major influent stream to the lake may be an important factor in stirring up bottom sediment in the vicinity of its inlet, although further core studies would be needed to establish this. Differential deposition of pollen in the lake was not discovered.

The magnitude of total pollen deposition rate did not vary greatly from place to place in the alpine area, nor did its character. Pollen deposited in winter and spring on the snow surface contained a high extra-alpine and

probably extra-montane component, although some montane and alpine pollen was present, the latter almost certainly eroded from areas in early winter and spring.

Although the magnitude of the stream pollen component was not finally known, it appeared to be important in the transport of pollen of certain taxa, e.g. Cyperaceae, Baecksea, and Filicinae, probably because these grew along the stream course. The rainout component of the pollen rain was small.

In the Geehi Valley, three pollen traps displayed great variations in total annual pollen deposition rate, and much pollen appeared to be local in origin. Both these traps and the alpine ones showed variations in magnitude and character of pollen catch associated with plant flowering periods.

The major contribution of the pollen transport study to the vegetation history study has been confirmation of the suspected origins of certain pollen taxa. It has also been shown that, while pollen influx into Blue Lake is composed of several different components, differential deposition in the lake does not appear to be a likely source of error at the scale of interpretation of the pollen diagram practised.

VEGETATION HISTORY AND CLIMATE

This has been summarised in Chapter 3. Before 17000 years B.P. there was little alpine vegetation. Climatic amelioration occurred such that, at 13000 years B.P., short alpine herbfield and feldmark communities, as well as local areas of fen, were present in the area of the Kosciusko Plateau. The most significant change in climate occurred at about 8700 years before present when rising temperatures raised the treeline from probable very low levels to at least its present position. This rise in temperature was accompanied by, or followed by rising available moisture, almost certainly therefore increased precipitation. This resulted in an extension of wetter understorey taxa of wet sclerophyll forest in the Geehi Valley to a greater area than at present occupied. Precipitation declined at 6600 years B.P., and declined further at 3800 years B.P. This may be correlated with a cold phase evidenced by periglacial features (Costin et al., 1967). Precipitation appears to have increased slightly since 1500 years B.P.

Churchill (1968) studied changes in Eucalyptus species distribution in south Western Australia by palynological methods. The study, at three bog sites, concluded that climate was wetter than at present from 6000 to 5000 years B.P., drier at about 2500 B.P. and between 750 and 450 B.P., finally wetter to the present. Dodson (1974), reporting pollen analysis of cores from Lake Keilambete in Victoria, and diatom analyses by Yezdani (1970) derived a similar climatic sequence, mainly from variations in the local vegetation. The sequence did, however, extend back to 10000 years B.P. Climate became wetter after 9700 years B.P., after which the climatic sequence follows that of Churchill, although the period of relative dryness was slightly earlier, at 3500 years B.P.

While the general change from dry to wet conditions, thence via decreasing wetness to a minimum at 3500 years B.P., is similar to that given above for the Kosciusko area, the time of onset of relative wetness in the Kosciusko region appears later. The date of 8600 to 9000 years B.P. for the start of bog formation appears to be well-founded, from both this and Costin's (1972) data. Possibly, as stated, the major control on vegetation in the region at this time was temperature, and not effective precipitation.

With regard to the expansion of wet sclerophyll forest understorey, the possibility of delayed migration into the area must be borne in mind, as in other parts of the world.

Addendum

Table D.10 (pp. 362A,-B) summarises the mean absolute rates of pollen deposition (in grains/cm²/year) measured in the Geehi Valley traps, Alpine area traps, snow cores, and Blue Lake pollen zones. The periods included in the trap estimates are:

Geehi Valley - Bella Vista 2 years (22.5.70 to 30.7.72)
 Claymore Creek 1 year (8.7.72 to 30.7.72)

Alpine Area - Summit, Col, Efflux 2 seasons (26.11.70 to 2.7.71,
 18.11.71 to 1.6.72)

 Delta, Hedley Tarn 1 season (18.11.71 to 1.6.72)

Although some trap results included refer to only one trapping season, it was felt that bias resulting from their inclusion would be more than offset by the greater number of results incorporated.

Following figures for each mean is the standard deviation of the contributory annual (Geehi Valley traps) or seasonal estimates (Alpine traps and snow cores), or individual Blue Lake core samples. Because of real inter-site and inter-level variability in pollen deposition rates, this standard deviation is often comparable in magnitude to the mean. The standard error of each mean can be approximated by dividing the corresponding standard deviation by the square root of the number of contributory estimates. For the trap and snow core results, this is not the total number of samples listed at the end of the table, but the number of sample groups, as follows:

Geehi Valley 4, Alpine Area 8, snow cores 8.

APPENDIX A
TAXONOMY OF SNOWY MOUNTAINS REGION PLANT MICROFOSSILS

This is divided into three sections:

1. A key to pollen and spore taxa identified in fossil, pollen trap, snow or water sample slides.
2. A key to microfossils (apparently not pollen or fern spores) present in the Blue Lake cores, with comments thereon.
3. A study of the pollen morphology of Apiaceae present in the region, with key to pollen types.

It is important that the keys be used in conjunction with the photographs and modern reference material should also be consulted. Certain pollen and spore types of rare occurrence, if not sufficiently distinctive for identification, were not included.

Nomenclature and the major groups of Key 1 are those of Faegri and Iversen (1964). Not all divisions are dichotomous, trichotomocarpate grains for example being divided into three tuberculate taxa. Terms such as colpus (for elongated aperture) and pore (for aperture less than twice as long as broad) are used in a morphological sense and are not meant to imply homology.

Numerals in brackets after the taxon name in Keys 1 and 2 refer to photograph numbers in plates A.1-A.7, which follow. The legend accompanying each plate lists the preparation yielding the photographed specimen (for codes, see Appendix D). Some taxa, for which only unsatisfactory photographs were available, were photographed from modern reference material (code REF, followed by family-genus-species laboratory code). All magnifications in the plates are 1000x, unless otherwise noted.

KEY 1. SNOWY MOUNTAINS REGION POLLEN AND SPORE TYPES

1. VESICULATE
- A. Bladders \pm the same size as body of grain,
with constriction between bladders and body
- B. Structure of bladder giving a fine
reticulate pattern in optical section..... *Pinus radiata* (1)
- BB. Bladder with elongated elements in optical
section..... *Podocarpus* comp. (2)
- AA. Bladders not constricted at base, not
extending far from body of grain. Bladder
with elongated elements in optical section.... *Dacrydium* comp. (3)
2. POLYPLICATE : none
3. INAPERTURATE
- A. Tectate grains with several elongated lacunae,
one of which forms a rudimentary pore at the
broad end of the usually pear-shaped grain..... *Cyperaceae* (84A)
- AA. Not so
- B. With scattered micro-gemmae. Usually
characteristically split..... *Callitris* (4)
- BB. Not so
- C. Tectate, with low verrucae..... *Ranunculus* (32)
- CC. Reticulate..... *Triglochin* (5)
4. MONOCOLPATE
- A. Spores. Exine without regularly arranged
collumellae, generally thick ($>2\mu$). Grains
generally large, $>30\mu$
- B. Psilate or scabrate..... *Filicinae* M (6)
- BB. Not so
- C. Verrucate or baculate
- D. Verrucae \pm circular, rounded in
section, low. Aperture usually
irregular..... *Cheilanthes* (7)

- DD. Verrucae irregular, flat-topped
in section. Aperture regular..... *Filicinae*
type 137 (8)
- DDD. Baculae irregularly arranged, some
fused..... *Hypolepis* (9)
- CC. Not so
- D. Reticulate
- E. Reticulum very coarse (about 6
brochi in equatorial view)..... *Asplenium* (10)
- EE. Reticulum finer, lace-like, with
variable-sized brochi..... *Polystichum*
proliferum (11)
- AA. Pollen grains. Exine with regularly arranged
columellae or reticulum (except *Astelia*).
Grains generally small, <35 μ (except *Xyris*)
- B. Reticulate..... *Liliaceae* subf.
Asphodeloideae
P.P. (12)
- BB. Not so
- C. Tectate, exine structure complex
(perhaps twice tectate). Grain $\geq 50\mu$ *Xyris* (13)
- CC. Not tectate, ornament of microechinae or
microtuberculae. Grain <25 μ *Astelia* (14)
- 5: TRICHOTOMOCOLPATE
- A. Spores. Columellae absent. Grain >30 μ (except
Pellaea)
- B. Psilate or minutely foveolate or scabrate
- C. Exine not thickened at angles in polar
view..... *Filicinae* T (14A)
- CC. Exine thickened at angles, distal
surface sometimes shallowly rugulate.... *Dicksonia*
antarctica (15)
- BB. Not so
- C. Sculpture reduced or absent on proximal
surface
- D. Equatorial outline \pm triangular

- E. Reticulate..... *Lycopodium*
fastigiatum (15A)
- EE. Foveolate..... *Lycopodium*
selago (17)
- DD. Equatorial outline \pm circular;
foveolate, commonly \pm rugulate..... *Ophioglossum* (16)
- CC. Not so
- D. Echinate. Subspherical, grain 20-30 μ .. *Pellaea falcata* (19)
- DD. Verrucate
- F. Verrucae \pm circular, about 2 μ
diameter, scattered..... *Grammitis* (20)
- FF. Verrucae dense, about 3 μ
diameter, fused along edge of
aperture..... *Culcita dubia* (21)
- FFF. Verrucae dense, about 1 μ
diameter, mostly \pm fused into
small groups..... *Filicinae*
type 156 (22)
- AA. Pollen grains. Columellae present. Grain
20-30 μ , subtriangular..... *Dianella sim.* (23)
6. MONOPORATE
- A. Pore without thickened annulus
- B. Reticulate. Grain 20-30 μ . Pore small..... *Typhaceae-*
Sparganiaceae (24)
- BB. Not so
- C. Foveolate. Pore very large, exine
fragmented or beaded around pore..... *Restionaceae* (25)
- CC. Microechinate. Pore or colpus large..... *Astelia* (14)
- AA. Pore with annulus. Tectate, psilate or
scabrate..... *Poaceae* (26)
7. DICOLPATE
- Grain prolate spheroidal, about 25 μ , near
syncolpate, reticulate..... *Atherosperma*
moschatum (27)

8. TRICOLPATE
- A. Tectate
- B. Psilate
- C. Columellae not clearly visible
- D. Exine thick (2-3 μ), ectexine thicker than endexine. Colpus equatorially constricted. Grain 20-30 μ , prolate... *Gyrostemonaceae* (28)
- DD. Exine thin (<2 μ), ectexine thinner than endexine. Colpus usually gaping. Grain <25 μ , \pm spherical..... *Gratiola* comp. (29)
- CC. Columellae clear
- D. Grain 20-30 μ , prolate..... *Parahebe* comp. (30)
- DD. Grain >35 μ *Euphrasia* (31)
- BB. Microechinate or microverrucate
- C. Echinae or verrucae broad, low. Scattered coarse columellae. Colpi narrow or diffuse..... *Ranunculaceae* (32)
- CC. Echinae or verrucae \pm equidimensional, dense. Colpi broad, open..... *Ewartia* comp. (33)
- AA. Per-reticulate
- B. Grains large (>40 μ), spheroidal..... *Prostanthera* (34)
- BB. Grains small (<30 μ)
- C. Colpus equatorially constricted
- D. Brochi reduced in size towards colpi. *Hypericum* comp. (35)
- DD. Not so
- E. Grain <20 μ . Several pores often visible along colpus..... *Bossiaea* sim. (68)
- EE. Grain >20 μ *Hovea* sim. (37)
- CC. Colpus not constricted equatorially
- D. Microreticulate, columellae not clearly discernible. Grain <20 μ , barrel-shaped..... *Daviesia* sim. (38)
- DD. At least some brochi >1 μ
- E. Colpi short (polar index >0.4). Exine 1-2 μ *Hibbertia* comp. (39)
- EE. Colpi long (polar index <0.2). Exine thick (2-4 μ)..... *Cruciferae* (40)

9. STEPHANOCOLPATE
- A. Colpi long
- B. Suprareticulate (columellate muri apparently overlying tectum). Grain 20-30 μ . Colpi 5-7, simple..... *Asperula* comp. (41)
- BB. Microechinate. Colpus membrane verrucate, margin irregular..... *Stylidium* (42)
- AA. Colpi short, pore-like, with thickened rim, protruding. Grain oblate..... *Haloragaceae* (43)
10. PERICOLPATE
- A. Grain large (>50 μ). Colpi 30, pentagonally arranged. Densely clavate..... *Neoparia australasica* (44)
- AA. Grain <25 μ . Colpi 6, tetrahedrally arranged. Reticulate..... *Daviesia* sim. (38)
11. DICOLPORATE : none
12. TRICOLPORATE
- 12:1. Psilate-scabrate
- A. With distinct costae equatoriales and equatorial transverse colpus. Prolate..... *Exocarpos* (45)
- AA. Costae equatoriales absent or indistinct
- B. Grain spheroidal or oblate : length/breadth ratio <1.2
- C. Intercolpium flattened or concave
- D. Exine thickest and columellae coarsest near the pole. Pore transversely oval *Hydrocotyle* sim. (46)
- DD. Not so. Pore \pm circular, with thickened rim..... *Pomaderris* (47)
- CC. Intercolpium convex
- D. Pore protruding
- E. Polar area small. Transverse colpus with distinct costae..... *Dodonaea* (48)

- EE. Polar area large. Grain scabrate,
distinctly oblate. Colpus
indistinct, pore circular..... *Acaena* (49)
- DD. Pore not protruding
- E. Polar area small, columellae
indistinct
- F. Pore obscure. Equatorial
outline lobed. Grain >15 μ *Utricularia* (50)
- FF. Transverse colpus. Equatorial
outline circular. Grain <15 μ ... *Tetratheca* (51)
- FFF. Pore \pm circular, with
thickened rim. Grain angular,
about 20 μ *Pomaderris* (47)
- EE. Polar area large. Columellae
distinct. Transverse colpus very
large. Grain rounded, oblate,
25-35 μ *Coprosma* (52)
- BB. Grain prolate : length/breadth ratio >1.2
- C. Grain quite prolate (length/breadth
ratio >1.8), large (>35 μ)
- D. Grain equatorially constricted or
with oblong meridional limb.
Transverse colpus with oval outline,
colpus narrow (<1 μ)..... *Dichosciadium*
ranunculaceum (53)
- DD. Grain with oval meridional limb.
Transverse colpus with oblong
outline, colpus broad (3 μ)..... *Correa*
Lawrenciana (54)
- CC. Not so
- D. Grain polarly asymmetrical, small
(<20 μ). Pore meridionally elongated,
oval, clear..... *Echium*
lycopsis (55)
- DD. Not so
- E. Transverse apertures two per
colpus. Columellae distinct (see
also section 12:5)..... *Myoporaceae* (56)
- EE. Not so

- F. Exine thickest in intercolpium or near poles. Transverse colpus or pore with costae. Prolate, oblong. Sometimes apiculate, generally colpi on flattened sides..... *Apiaceae* (57,58)
(see Key 3)
- FF. Not so
- G. Meridional limb rhomboid. Exine thick (2-3 μ). Pore transversely 8-shaped..... *Tieghemopanax sambucifolius* (61)
- GG. Meridional limb oval. Pore oval, with distinct costae, slightly protruding. Grain >25 μ *Dodonaea* (48)

12:2. Echinate

- Asteraceae* subfam. *Tubuliflorae* (94A)
(see section 8:3 for verrucate tricolpate grains - *Ewartia* comp. - and section 21 for fenestrate grains - *Asteraceae* subfam. *Liguliflorae*).

12:3. Striate-rugulate

- A. Grain <25 μ , slightly oblate. Striate : groups of \pm parallel striae meeting at abrupt angle in median of intercolpium..... *Centaurium* (59)
- AA. Grain >30 μ , prolate. Striate (semitectate), striae all \pm meridional..... *Gentianella diemensis* (60)

12:4. Suprareticulate-foveolate

- A. Grain oblate, 20-25 μ . Colpus short, pore meridionally elongated. Equatorial limb sub-triangular with colpi at angles. Reticulum fine, imperfect..... *Indigofera* comp. (62)
- AA. Not oblate, colpus long. Reticulum coarser, clear, reduced towards colpi. Colpus equatorially constricted

- B. Pore and columellae indistinct..... *Hardenbergia* sim. (63)
- BB. Pore clear, without costae, \pm circular.
Columellae distinct..... *Trifolium* sim. (64)
- 12:5. Per-reticulate
- A. With transverse colpus or equatorially elongated pore exceeding width of colpus
(*Rutaceae* P.P.)
- B. Reticulum coarse (brochi to 1μ). At least slightly prolate..... *Eriostemon* sim. (65)
- BB. Reticulum fine (brochi $<0.5\mu$). Grains \pm spheroidal, equatorial limb inter-hexagonal..... *Phebalium* comp. (66)
- AA. Not so
- B. Grain large ($>30\mu$). Reticulum with meridionally elongated brochi. Columellae distinct..... *Gentianella diemensis* (60)
- BB. Not so
- C. Colpi commonly not perfectly meridional, very narrow. Pore \pm circular, with costae. Grain spheroidal to slightly oblate..... *Rumex* (67)
- CC. Not so
- D. Several pores along colpus, or single very elongated pore.
Reticulum very fine (brochi $<0.7\mu$).
Grain $<20\mu$, spheroidal to slightly prolate..... *Bossiaea* sim. (68)
- DD. Single \pm circular pore within colpus.
Reticulum coarser (brochi to 1μ),
reduced towards colpi. Grain $<20\mu$ *Bursaria spinosa* (69)
13. STEPHANOCOLPORATE
- A. With 6 or fewer colpi..... *Boraginaceae* (70)
- AA. With 10 or more colpi. Equatorial girdle of fused transverse colpi..... *Polygalaceae* (71)

14. PERICOLPORATE

- A. Colpi 4, very narrow. Pores \pm circular, covered, with costae. Pattern (micro-)per-reticulate. Grain \pm spheroidal, $<30\mu$. Limb lobed between colpi..... *Rumex* (67)
- AA. Colpi ≥ 4 , narrow. Pores \pm circular, with costae and annuli, not patterned. Tectate, columellae indistinct, scabrate to psilate. Limb polygonal..... *Pomaderris* (47)

15. DIPORATE

- Grain bean-shaped, apertures at the ends, about $30 \times 20 \times 20\mu$ (excluding convex pore membranes). Tectate. Pore with distinct costa and more coarsely structured ectexinal annulus..... *Banksia* id.
marginata comp. (72)

(*Banksia* is the only regular representative in the area. Exceptional grains of Haloragaceae, Casuarina, etc., are diporate).

16. TRIPORATE

- A. Pore at apex of large \pm dome-shaped protrusion with basal 'costal' ring of thickened exine (vestibulate)
- B. Grain $\geq 50\mu$ *Epilobium* (73)
- BB. Grain $<40\mu$ (occasionally 2-, 4-, 5- porate) .. *Casuarina* (74)
- AA. Not so
- B. Equatorial limb \pm triangular, with truncate apices (at pores). Pores not markedly thickened at rim, but with costae at some distance from aperture
- C. Tectate
- D. Tuberculate..... *Hakea* (75)
- DD. Psilate or scabrate..... *Grevillea* sim. (77)
- CC. Per-reticulate..... *Lomatia* (76)

- BB. Equatorial limb \pm circular
- C. With distinct spines, tectate. Pores with costae..... *Wahlenbergia* (78)
- CC. Not so
- D. Pore not thickened. Grain $<20\mu$ *Urticaceae* (79)
- DD. Pore with sharply delimited thickened annulus. Tectate, columellae fine. Grain $>20\mu$ *Myriophyllum pedunculatum* (80)
17. STEPHANOPORATE
- A. With distinct, regularly distributed spines.... *Wahlenbergia* (78)
- AA. Psilate or scabrate
- B. With protruding vestibulate pores..... *Casuarina* (74)
- BB. Pores with endexine thickenings, protruding (equatorial limb irregular), meridionally elongated..... *Haloragaceae* p.p. (43)
18. PERIPORATE
- A. Verrucate
- B. Pores distinct, with annuli. Sculpture fine. *Plantago id. lanceolata* sim. (81)
- BB. Pores indistinct, without annuli. Sculpture coarse..... *Plantago id. muelleri* sim. (82)
- AA. Echinata (no examples)
- AAA. Reticulate
- B. Bottom of lumina either with a pore or covered by granules. Reticulum very coarse and regular..... *Polygonum* (83)
- BB. Pores distinct, surrounded by annuli with \pm wedge-shaped ectexine elements ('croton' pattern), the annuli forming part of a reticulum in which other brochi are smaller..... *Pimelea* sim. (84)
- AAAA. Psilate-scabrate

- B. Grain irregular, usually pear-shaped.
 Pores indistinct..... *Cyperaceae* (84A)
- BB. Not so
- C. Grain $>25\mu$, polyhedral. Pores 12, large
 ($>5\mu$), sunken. Exine tectate, punctate,
 with minute tuberculae or echinae..... *Stellaria* (87)
- CC. Not so. Pores >12 , small ($<3\mu$). Tectate,
 punctae indistinct or absent. Grain
 spheroidal
- D. Pores clear, \pm rimmed..... *Centrospermae* p.p. (85)
- DD. Pores indistinct. Grain $25-30\mu$ *Centrospermae* sim.
 type 74. (86)
19. SYNCOLPATE
- A. Colpi meridional
- B. Tricolpate. Equatorial limb triangular with
 deeply concave sides. Colpi meeting neatly,
 without polar lacunae. Grain $25-30\mu$ *Amyema* (88)
- BB. Tricolporate (occasionally dicolporate or
 tetracolporate in *Eucalyptus*). Equatorial
 limb triangular, sides slightly concave,
 straight or convex
- C. Colpi meeting in \pm triangular polar area
- D. Grain $<15\mu$. Polar area with triangular
 'island' of patterned exine. Clear
 vestibulum at pore..... *Callistemon* comp. (89)
- DD. Grain without patterned polar
 'island', or if so, $>15\mu$. Vestibulum
 not clear..... *Eucalyptus* (90)
- CC. Colpi meeting without enclosing marked
 polar area
- D. Colpi interrupted or attenuated
 between polar and equatorial areas..... *Angophora* (91)
- DD. Not so
- E. Sculpture a faint, relatively
 coarse reticulum, or psilate..... *Leptospermum* sim. (92)
- EE. Distinctly microverrucate..... *Kunzea* comp. (93)
- AA. Colpi spiral-shaped. Grain \pm oblong (fragment
 of polyad)..... *Acacia* (94)

20. HETEROCOLPATE : none

21. FENESTRATE

Echinate, lophate. Lacunae in a distinct pattern.. *Asteraceae* subfam.
Liguliflorae (94A)

22. DYADS : none

23. TETRADS

A. All but one grain reduced and forming cap at
lesser pole of polarly assymmetrical ±
prolate tricolporate major grain..... *Monotoca* comp. (95)

AA. Not so

B. Reticulate, each grain distally monoporate.. *Drimys* (96)

BB. Not so

C. Verrucate-gemmate, each grain tricol-
porate (but this may be difficult to
observe)..... *Epacris*
serpyllifolia (97)

CC. Scabrate or psilate

D. Each grain tricolporate..... *Epacridaceae* p.p. (98)

DD. Each grain triporate. Pores
vestibulate. Grains loosely
connected..... *Epilobium* (73)

24. POLYADS

Grains usually 12 or 16 per polyad. Polyads oval
and bilaterally symmetrical..... *Acacia* (94)

KEY 2. MICROFOSSILS OTHER THAN POLLEN AND SPORES

A number of microfossils was recognised but only those which occurred frequently are described.

- A. Organism colonial (palmellate), consisting of an approximately spheroidal mass of radiating funnel-shaped cells, about 30 μ diameter. May be aggregated with similar masses. Generally yellow-brown in colour..... *Botryococcus*
braunii (100)
- AA. Organism single-celled
- B. Spheroidal or slightly oblate spheroidal
- C. Pattern of meridionally arranged verrucae or short spines. Diameter 18-22 μ . Wall about 1 μ thick..... 'Sphere-R' (104)
- CC. Pattern reticulate. Brochi angular, about 2-3 μ in diameter. Wall about 1 μ thick. Diameter 20 μ 'Sphere-F' (103)
- CCC. Pattern reticulate. Muri formed by outwards-folding of wall, which is not thickened. Brochi about 5 μ , 5-7 sided. Diameter 25-30 μ 'Sphere-P' (102)
- CCCC. Pattern faintly but distinctly scabrate. Diameter 15-20 μ 'Sphere-W' (99)
- BB. Prolate, about 50-60 x 35-45 μ . Ornament of thicker, tubiform (although not clearly hollow) processes, apically expanded. These appear to support a thin outer membrane; the inner, basal layer is split by a narrow aperture (3/4 of the length of the body)..... *Baltisphaeridium*
sp. X. (101)

Affinities of these microfossils

- 1) *Botryococcus braunii* Kutzing is a well known alga of varied habitats, both fresh- and salt-water (Blackburn and Temperley, 1936). It was recorded in 1970 from ponds near Lake Albina (Powling, 1970), but not from Blue Lake. It is, however, well known in Australian

sedimentary deposits (e.g. Cookson, 1953).

- 2) Spheres -R, -F, -P, -W. The general morphology and ornament of these types distinguish them from the spores of vascular plants and bryophytes. Fossil fungi tend to appear a characteristic brown colour, although this is not likely to be an infallible guide. The most likely affinities of these forms are, however, with the algae*. Churchill (1960a) has recorded fossil unicellular algae and aplanospores from southwest Australian freshwater peats, but none of these appear to be closely similar to the above. However more or less spheroidal unicellular algae occur in several algal groups (Fritsch, 1956; Bourrelly, 1966; Prescott, 1954); the spores of still other algae have similar form.

Algal genera which should be considered are:

- Sphere - R : Trochiscia (Oocystaceae)
Akanthochloris (Pleurochloridaceae)
 Sphere - F : Arachnochloris (Pleurochloridaceae)
 Sphere - P : Trochiscia - strong similarity
Nautococcus (Hypnomonadaceae)
Arachnochloris
 Sphere - W : Chlorella (Oocystaceae)
Chlorococcum (Chlorococcaceae)
Pleurochloris (Pleurochloridaceae)
Chloridella (Pleurochloridaceae)

Only the capture, and possibly culture, of live organisms is likely to resolve the question further.

- 3) Baltisphaeridium spp. These have been described from freshwater deposits in southwestern Australia (Churchill & Sarjeant, 1962) and also occur in eastern Australia in the Mt. Gambier region lakes (Mr. J.R. Dodson, pers. comm.) and Lake George (Dr. G. Singh, pers.

* Powling's identifications of phytoplankton from lakes in the Kosciusko area contain no mention of forms which could be identified with these spheroidal forms, and, indeed, no record of any phytoplankton from Blue Lake (save the green filamentous alga Ulothrix) on either sampling occasion (February 1969, February 1970). The net used was of 60 micron mesh size, hence it is possible that the organisms passed through the net, particularly since clogging of the mesh by larger plankton did not occur. Hydrological conditions during the sampling may also have meant that the organisms, if present, were concentrated elsewhere in the lake. Peak frequency of the organisms may also occur at other times during the ice-free season.

comm.). They are assigned by Churchill and Sarjeant to the order and family Hystrichosphaeridea : Hystrichosphaeridae, a family of form genera, many of which have apparent dinoflagellate affinities (Evitt, 1961). The authors point out however, that the species of Baltisphaeridium described show no undoubted features of dinoflagellate affinity. Following a proposal by Evitt (1963), Sarjeant later placed the genus in a group incertae sedis, the Acritarcha.

The form B. sp. X shows some similarities to B. telmaticum, but in the Blue Lake form all processes seem to be of the same character. The presence of a supra-process membrane is not mentioned by Churchill and Sarjeant for any of the forms described by them, but similar membranes occur in the cysts of pre-Neogene dinoflagellates (Sarjeant, 1969 : e.g. Membranilarnacia). A simple slit-like aperture or furrow occurs in B. quaternarium Churchill & Sarjeant (this form has simple spines). This could correspond to the ventral pore of a dinoflagellate.

Plate A.1

<u>Photo No.</u>	<u>Taxon</u>	<u>Location</u>	<u>(Magnification)</u> (x1000 unless noted)
1	<u>Pinus radiata</u>	SN70 B	(x500)
2	<u>Podocarpus</u> comp.	BL1 257 1	(x500)
3	<u>Dacrydium</u> comp.	TCA 145	
4	<u>Callitris</u>	BL1 177 1	
5	<u>Triglochin</u>	BL3 60 1	
6	Filicinae-Monolete	BL1 317 1	
7a,b	<u>Cheilanthes</u>	BL1 317	
8a,b	Filicinae type 137	BL1 397 1	
9a,b	<u>Hypolepis</u>	BL3 140 1	
10a,b	<u>Asplenium</u>	REF 407-21-1-8	
11	<u>Polystichum</u>	BL1 397 1	
12a,b	Liliaceae subf. Asphodeloideae	BL1 257 1, BL3 340 1	
13	<u>Xyris</u>	BL3 280 1	
14a,b	<u>Astelia</u>	BL1 317 1	
14A	Filicinae-Trilete	BL3 200 1	

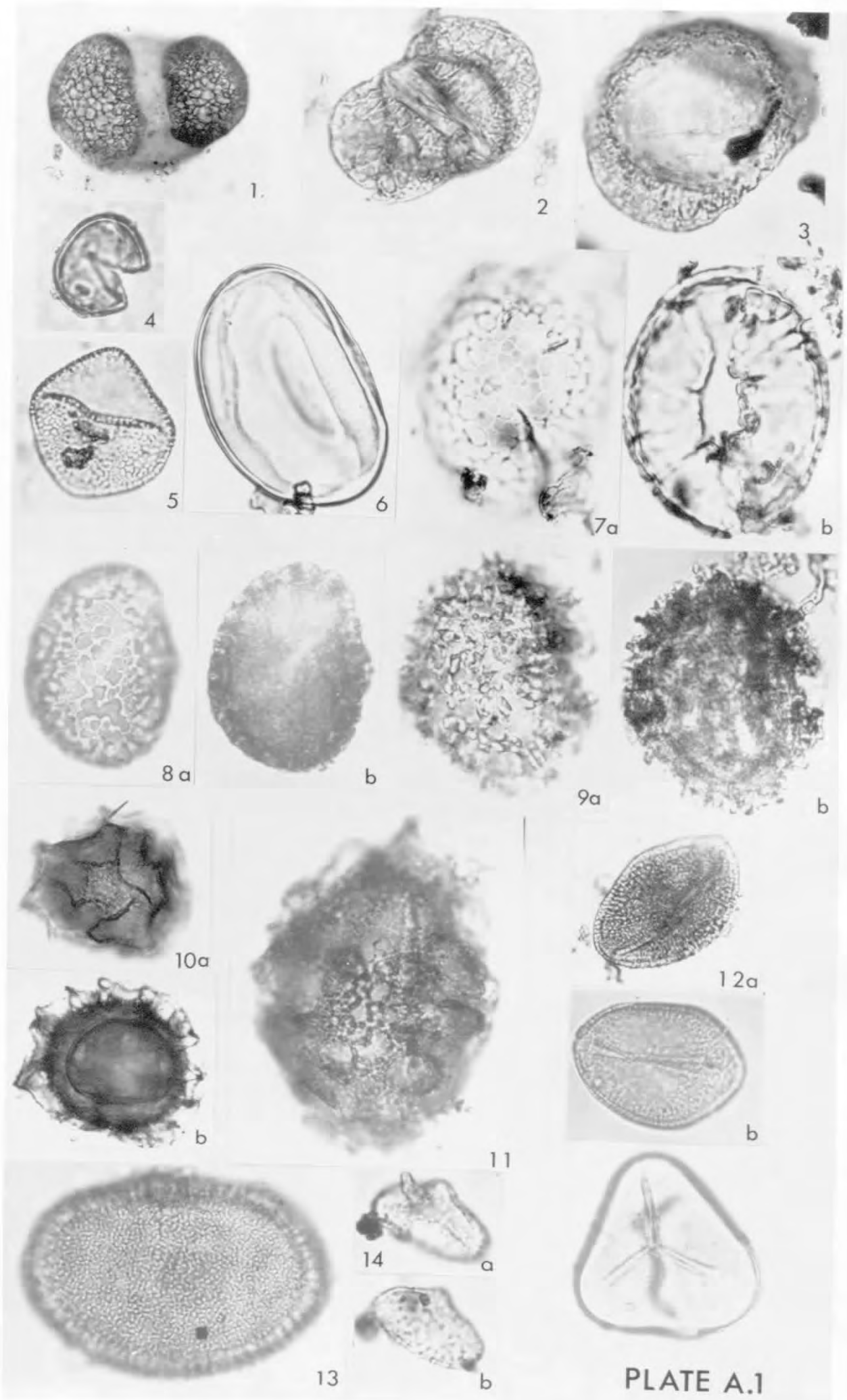


PLATE A.1

Plate A.2

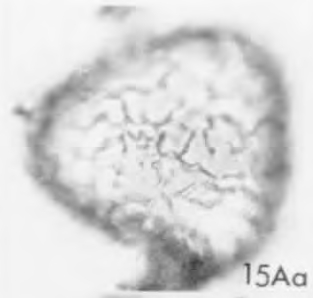
<u>Photo No.</u>	<u>Taxon</u>	<u>Location</u>
15a,b	<u>Dicksonia antarctica</u>	BL1 197 1
15Aa,b	<u>Lycopodium fastigiatum</u>	BL1 77
16	<u>Ophioglossum</u>	BL3 60 1
17	<u>Lycopodium selago</u>	BL1 77
19a,b	<u>Pellaea falcata</u>	BL1 37 1
20a,b	<u>Grammitis</u>	BL1 357 1
21a,b	<u>Culcita dubia</u>	BL3 240 1
22	Filicinae type 156	BL3 100 1
23	<u>Dianella</u>	REF 32-18-2
24a,b	Typhaceae-Sparganiaceae	BL1 417 1
25a,b	Restionaceae	BL3 180 1
26a,b	Poaceae	BL3 380 2



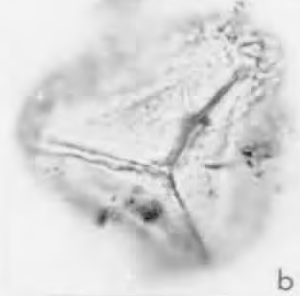
15a



b



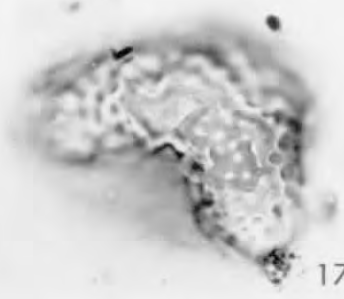
15Aa



b



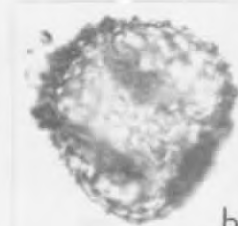
16



17



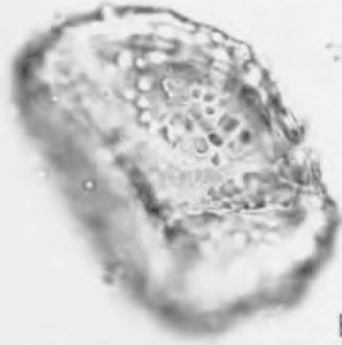
19a



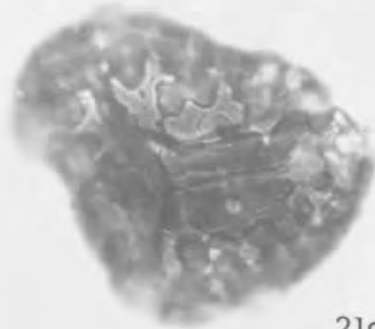
b



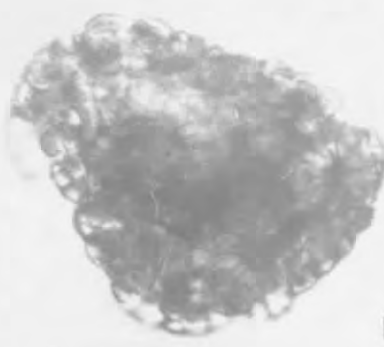
20a



b



21a



b



22



23



24a



b



25a



b



26a



b

PLATE A.2

Plate A.3

<u>Photo No.</u>	<u>Taxon</u>	<u>Location</u>
27a,b	<u>Atherosperma moschatum</u>	REF 100-2-1a
28	Gyrostemonaceae	BL1 337 2, BL1 77
29a,b	<u>Gratiola</u> comp.	BL3 160 1
30	<u>Parahebe</u> comp.	BL1 397
31a,b	<u>Euphrasia</u>	BL3 240 1
32a,b	Ranunculaceae	BL3 118 1, BL1 237 1
33	<u>Ewartia</u> comp.	BL3 400 3, TCA 145
34	<u>Prostanthera</u>	BL1 157 1
35	<u>Hypericum japonicum</u>	REF 189-1-1
37a,b	<u>Hovea</u> sim.	TCA 90
38a,b,c,d	<u>Daviesia</u> sim.	TCA 35, BL1 317 1
39a,b	<u>Hibbertia</u> comp.	BL1 177 1
40a,b	Cruciferae	BL1 157 1
41a,b	<u>Asperula</u> sim.	BL1 137 2
42	<u>Stylidium</u>	BL1 337 1
43a,b,c	Haloragaceae	BL3 20 1, BL3 360 1
44	<u>Neopaxia australasica</u>	BL1 37 1
45a,b	<u>Exocarpos</u>	REF 65-3-6c
46a,b	<u>Hydrocotyle</u> sim.	BL1 317 2
47a,b	<u>Pomaderris</u>	BL1 197 1

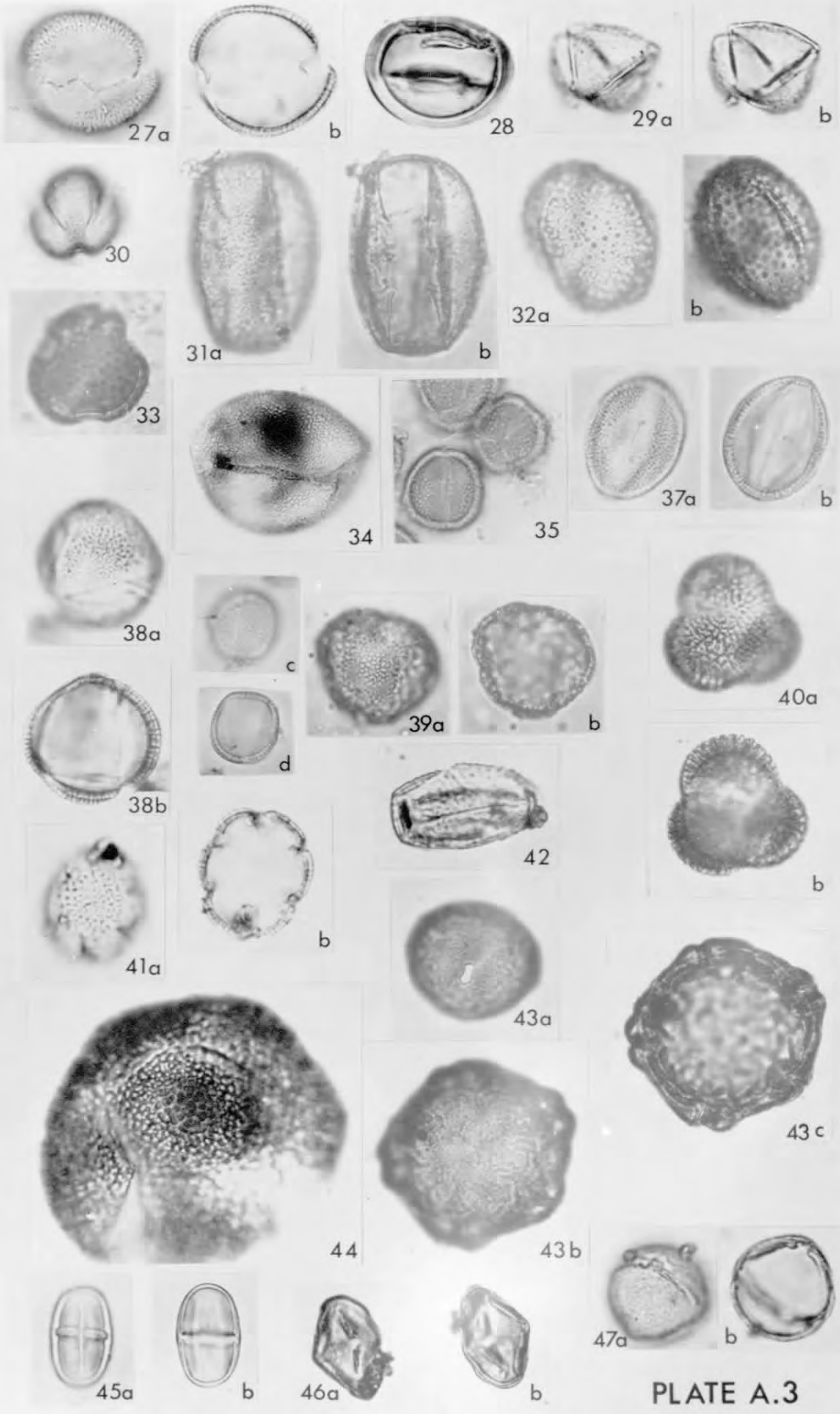


PLATE A.3

Plate A.4

<u>Photo No.</u>	<u>Taxon</u>	<u>Location</u>
47c,d	<u>Pomaderris</u>	BL3 100 1
48a,b,c	<u>Dodonaea</u>	BL1 417 1, BL1 297 1
49	<u>Acaena</u>	BL1 217 1
50a,b	<u>Utricularia</u> comp.	BL1 217 1
51	<u>Tetradthea</u>	BL3 220 1
52a,b,c	<u>Coprosma</u>	BL3 180 1, BL3 240
53a,b	<u>Dichosciadium</u> <u>ranunculaceum</u>	B13 0 1
54a,b	<u>Correa lawrenciana</u>	REF 139-6-3a
55	<u>Echium lycopsis</u>	SN68 B
56a,b	Myoporaceae	BL1 77, M3 0 1
57a,b	<u>Aciphylla</u> sim.	BL1 297 2
58	<u>Schizeilema fragoseum</u>	BL1 297 2, BL1 317 2
59a,b	<u>Centaurium erythaea</u>	REF 250-1-4
60	<u>Gentianella diemensis</u>	BL1 337 2
61a,b	<u>Tieghemopanax</u> <u>sambucifolius</u>	BL1 277 1
62a,b	<u>Indigofera australis</u>	REF 129-12-1
63a,b	<u>Hardenbergia</u> sim.	BL1 397 1, BL3 380 1
64a,b	<u>Trifolium</u> sim.	BEV 2
65a,b	<u>Eriostemon</u> sim.	BEV 2
66	<u>Phebalium</u> comp.	BL1 377 1
67a,b	<u>Rumex acetosella</u>	SN70 B

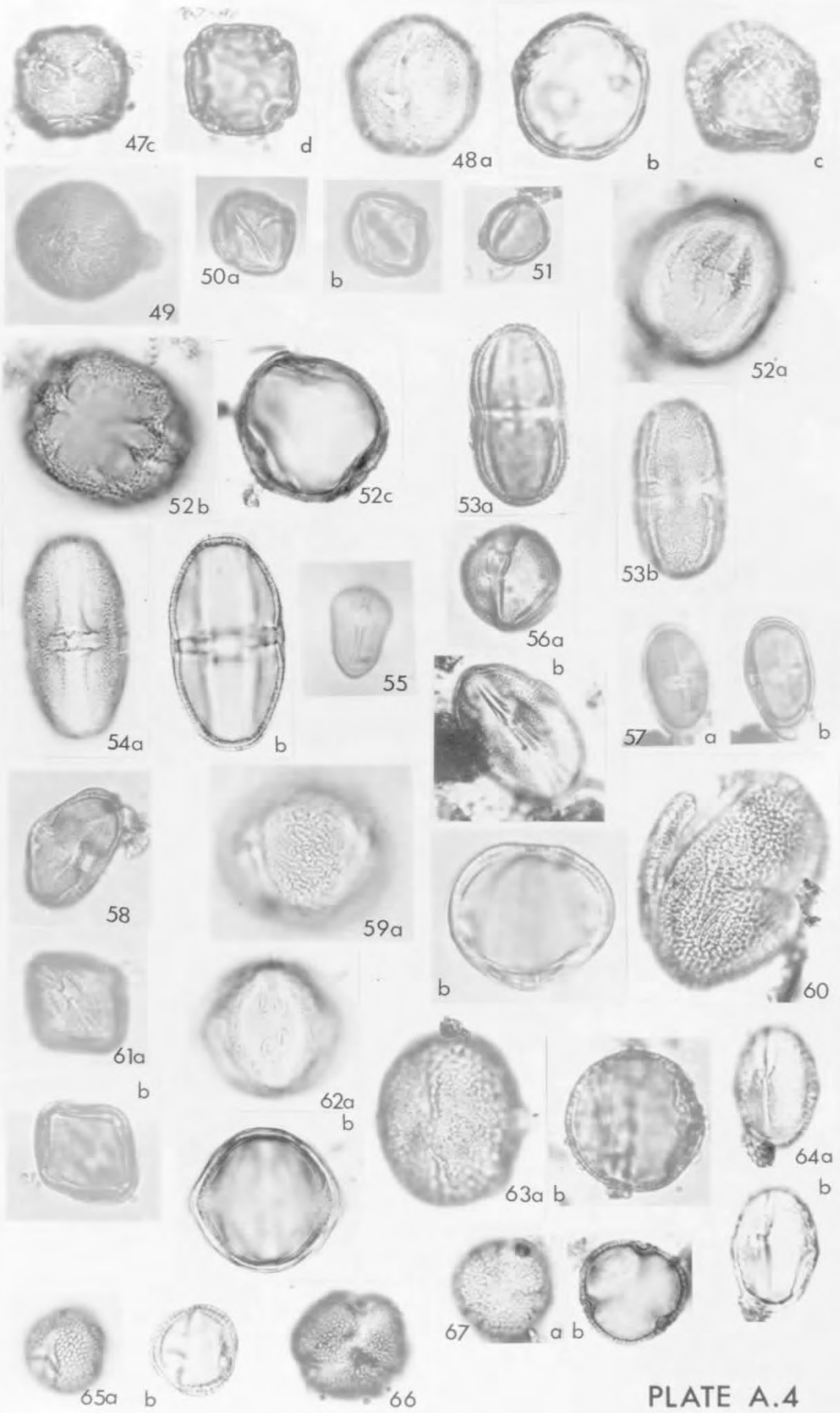


PLATE A.4

Plate A.5

<u>Photo No.</u>	<u>Taxon</u>	<u>Location</u>
68a,b	<u>Bossiaea</u> sim.	BEV 2
69a,b	<u>Bursaria spinosa</u>	BL1 297 1
70a,b	Boraginaceae	SN71 2-1
71a,b	<u>Comesperma volubile</u>	REF 147-2-7
72a,b,c	<u>Banksia marginata</u> comp.	BL3 118 1, M3 60 1
73a,b	<u>Epilobium confertifolium</u>	REF 227-1-7
74a,b	<u>Casuarina</u>	BL1 337 1, BL1 77
75	<u>Hakea</u>	BL1 337 2
76a,b	<u>Lomatia</u>	CCL 7
77	<u>Grevillea</u> sim.	DEL 6
78a,b	<u>Wahlenbergia</u>	BL1 397
79	Urticaceae	BL3 57 1
80	<u>Myriophyllum</u> <u>pedunculatum</u>	BL3 57 1
81a,b	<u>Plantago lanceoloata</u> sim.	BEV 2
82	<u>Plantago muelleri</u> sim.	BL1 17 1, BL1 177 1
83a,b	<u>Polygonum hydropiper</u>	REF 75-2-27
84a,b	<u>Pimelea</u>	BL1 137 1
84A	Cyperaceae	BL1 297 1

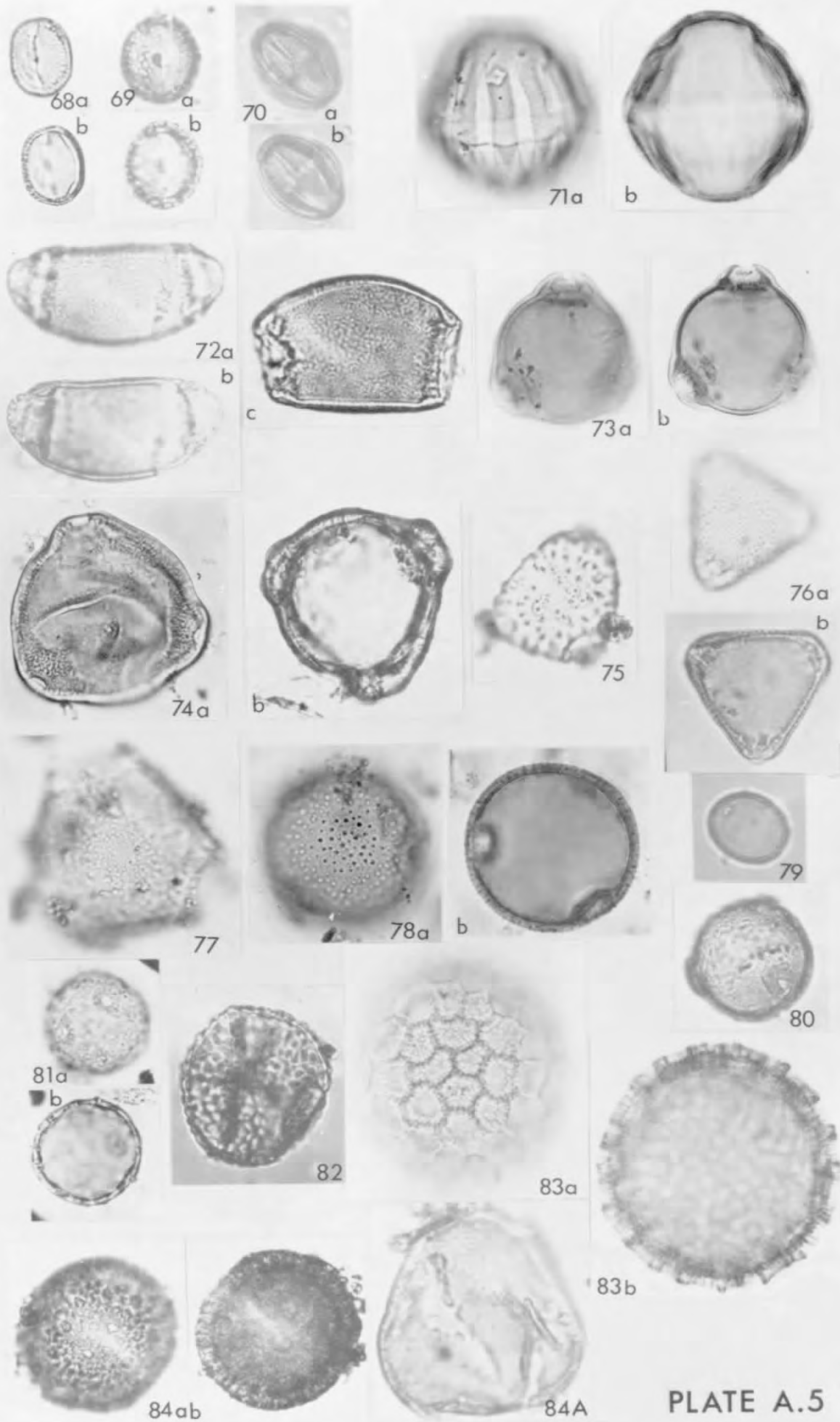


PLATE A.5

Plate A.6

<u>Photo No.</u>	<u>Taxon</u>	<u>Location</u>
85a,b	Centrospermae I & II	BL1 77, BL1 257 1
86a,b	Centrospermae type 74	BL1 417 1
87a,b	<u>Stellaria</u>	SUM 6
88	<u>Amyema</u>	BL3 260 1
89	<u>Callistemon sieberi</u>	REF 225-2-3a
90a,b,c,d	<u>Eucalyptus</u>	BL1 297 2
91	<u>Angophora</u>	BL1 357 2
92a,b,c	<u>Leptospermum sim.</u>	BL1 317 1, 2
93a,b	<u>Kunzen muelleri</u>	REF 225-1-2a
94a,b	<u>Acacia</u>	BL1 157 1
94A	Asteraceae subf. Liguliflorae	BEV 2
95a,b	<u>Monotoca comp.</u>	BL1 297 2
96	<u>Drimys</u>	BL3 20 1
97	<u>Epacris serpyllifolia</u>	BL1 77 1, BL1 437 1
98a,b	Epacridaceae	BL1 77 1
99a,b,c	'Sphere - W'	BL3 380 2
100a,b	<u>Botryococcus braunii</u>	BL1 77

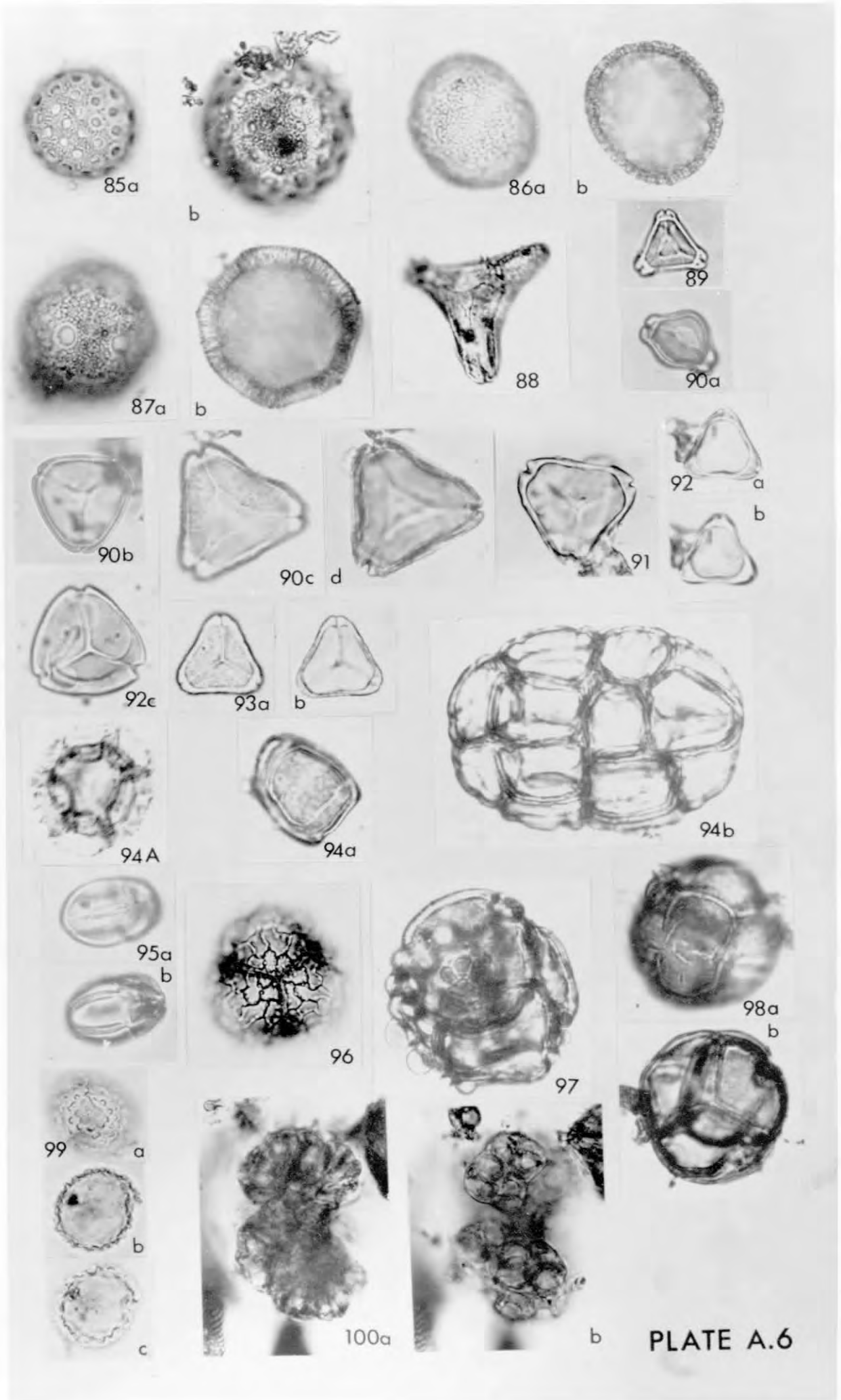
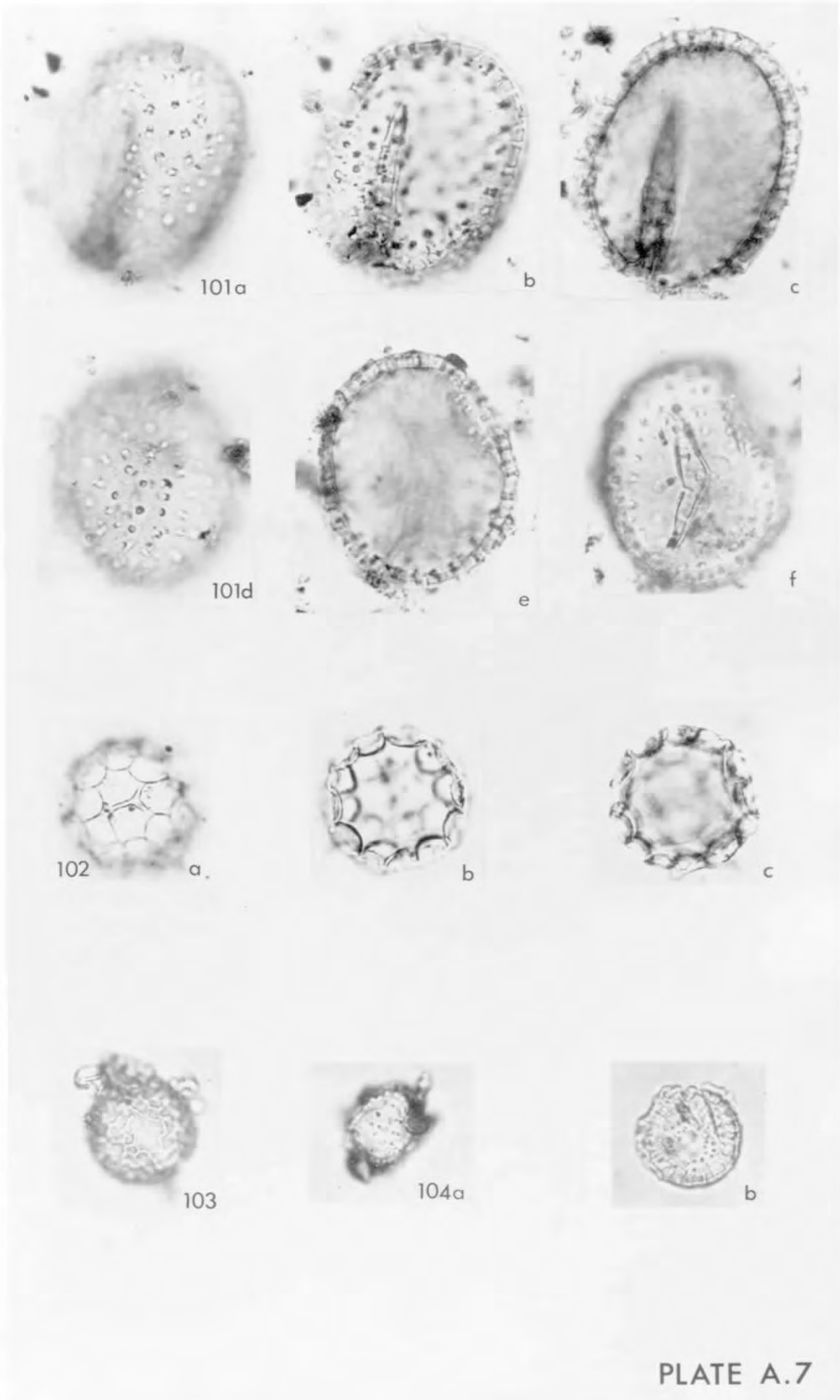


PLATE A.6

Plate A.7

<u>Photo No.</u>	<u>Taxon</u>	<u>Location</u>
101a,b,c,d,e,f	<u>Baltisphaeridium</u> sp.	BL1 77 (high, median, low focus)
102a.b.c	'Sphere - P'	BL3 160 1
103	'Sphere - F'	BL1 397 1
104a,b	'Sphere - R'	BL1 317 1, B11 237 1



KEY 3. POLLEN OF APIACEAE IN THE SNOWY MOUNTAINS

Native species only are keyed and described here. Alien species, uncommon except near settlements, include the following (Willis, 1972; Burbidge and Gray, 1970): Anethum graveolens L., Apium leptophyllum (Pers.) F. Muell ex Benth., Conium maculatum L., Foeniculum vulgare Mill. The native species Lilaeopsis polyantha (Gandoger) Hj.Eichler may occur at lower elevations, but no reference material was available. Only two of the many species of Hydrocotyle listed from the region were selected for study. These two had very similar morphology. The two species of Seseli are of interest in that Dawson (1967) has suggested they be referred to Gingidium J.R. et G. Forst. In a study of New Zealand Gingidium species Moar (1966) distinguished three groups based on pollen morphology. The pollen of Seseli algens closely resembles that of Moar's Gingidium montanum group (i.e. that of the type species), while that of S. harveyanum more closely resembles his G. deltoideum group.

- A. Length of grain $>30\mu$, equator constricted
- B. Grain $>40\mu$. Exine with \pm striate pattern.... Trachymene anisocarpa
- BB. Grain $<40\mu$. Not striate..... Dichosciadium
ranunculaceum
- AA. Equator not constricted. Grain $<35\mu$.
- B. Pore equatorially 8-shaped (constricted at colpus)
- C. Apertures at angles of equatorial limb (\pm apiculate)
- D. Pores markedly protruding..... Daucus glochidiatus
Eryngium rostratum
Seseli algens
- DD. Not so (outline of pore obscure)..... Seseli harveyanum
- CC. Apertures between lobes or angles of equatorial limb..... Aciphylla spp.
Diplaspis hydrocotyle
Oreomyrrhis spp.
- BB. Pore not 8-shaped

- C. Pore circular or equatorially elongated... *Centella cordifolia*
Eryngium vesiculosum
Hydrocotyle spp.
Oschatzia cuneifolia
Platysace lanceolata
Seseli harveyanum
Trachymene humilis
- CC. Pore meridionally elongated, oblong.
 Grain apiculate, c. 20 μ long..... *Schizeilema fragoseum*

For details of measurements, etc., see Tables A.1, A.2. Slides were prepared from herbarium material by the usual methods of the A.N.U. Department of Biogeography and Geomorphology Palynology Laboratory, including acetolysis, dehydration in alcohol, and mounting in silicone oil (AK2000, cf. Andersen, 1960). Examination was carried out with a Carl Zeiss (Oberkochen) automatic photomicroscope. Measurements were made to an accuracy of one eyepiece division (0.625 μ) on a 10-grain unbiased sample from each slide, using a total magnification of x1600 (oil immersion objective). The same optical arrangement was used for morphological examination and photography. For photomicrographs, see Plates A.8, A.9, and Table A.1 (legend).

Table A.1 Apiaceae Material and Key to Photographs
Plates A.8 & A.9

<u>Name</u>	<u>ANU</u> <u>Accession</u> <u>No.</u>	<u>Photo</u> <u>Nos.</u>
<u>Aciphylla glacialis</u> (F. Muell.) Benth	3459	1
<u>A. simplicifolia</u> (F. Muell.) Benth	3460	2
<u>Centella cordifolia</u> (J.D. Hook.) Nannfeldt	6139	3
<u>Daucus glochidiatus</u> (Labill.) Fisch et al.	3464	4
<u>Dichosciadium ranunculaceum</u> (F. Muell.) Domin	3465	5
<u>Diplaspis hydrocotyle</u> J.D. Hook.	3581	6
<u>Eryngium rostratum</u> Cav.	3468	7
<u>E. vesiculosum</u> Labill.	5440	8
<u>Hydrocotyle hirta</u> R.Br. ex A. Rich	3469	9
<u>H. laxiflora</u> DC.	5444	10
<u>Oreomyrrhis brevipes</u> Mathias & Constance	3579	11
<u>O. ciliata</u> J.D. Hook	3585	12
<u>O. eriopoda</u> (DC.) J.D. Hook	3587	13
<u>O. pulvinifica</u> F. Muell.	3470	14
<u>Oschatzia cuneifolia</u> (F. Muell.) Drude	3578	15
<u>Platysace lanceolata</u> (Labill.) Norman	3473	16
<u>Schizeilema fragoseum</u> (F. Muell.) Domin	3474	17
<u>Seseli algens</u> F. Muell.	3479	18
<u>S. harveyanum</u> F. Muell.	3475	19
<u>Trachymene anisocarpa</u> (Turcz.) B.L. Burtt	7645	20
<u>T. humilis</u> (J.D. Hook.) Benth.	3478	21

Table A.2

	<u>Apiaceae Measurements</u>					
	<u>Polar Diameter</u>	<u>Equatorial Diameter</u>	<u>Pore Height</u>	<u>Pore Width</u>	<u>Pore Shape (to scale)</u>	
<u>Aciphylla glacialis</u>	20(22.0)26	12(13.8)15	2.2-2.8	4.4-5.6		
<u>A. simplicifolia</u>	19(20.4)25	12(13.1)14	2.5(2.8)3.1	4.4(4.8)6.3		
<u>Centella cordifolia</u>	22(25.8)29	14(14.8)16	1.9(2.2)2.5	3.1(3.7)4.4		
<u>Daucus glochidiatus</u>	22(24.9)27	15(16.2)17	1.6(2.2)3.1	3.7(4.6)5.6		
<u>Dichosciadium ranunculaceum</u>	34(37.4)41	16(18.1)20	2.2(3.0)4.4	4.4(5.6)6.3		
<u>Diplaspis hydrocotyle</u>	21(21.9)23	12(13.8)16	1.6(1.8)1.9	4.3(4.7)5		
<u>Eryngium rostratum</u>	32(34.8)37	19(23.5)26	5(7.2)8	5(7.9)9		
<u>E. vesiculosum</u>	37(40.1)43	20(24.4)28	4.1(5.4)6.3	8.8(10.1)12.5		
<u>Hydrocotyle hirta</u>	23(24.8)27	16(17.0)18	1.6(2.0)2.4	3.7(4.3)5		
<u>H. laxiflora</u>	27(28.7)30	21(23.1)25	2.5(2.8)3.1	4.4(6.8)8.7		
<u>Oreomyrrhis brevipes</u>	17(18.9)20	9(10.3)11	1.6(2.2)3.1	4.1(4.5)5		
<u>O. ciliata</u>	19(20.8)24	11(11.2)13	1.9(2.3)2.8	3.8(4.5)5.3		
<u>O. eriopoda</u>	19(22.3)26	10(12.4)17	1.3(2.1)2.5	4.4(5.1)6.3		
<u>O. pulvinifica</u>	19(21.0)23	11(12.6)14	1.9(2.4)2.8	4.4(4.9)6		
<u>Oschatzia cuneifolia</u>	26(28.6)30	15(17.0)19	2.8(3.5)4.1	2.5(3.6)4.4		
<u>Platysace lanceolata</u>	20(24.3)29	14(15.9)19	1.6(2.4)2.8	3.7(4.3)6.3		
<u>Schizeilema fragoseum</u>	20(21.5)23	12(13.6)15	1.9(2.7)3.4	1.9(2.3)3.4		
<u>Seseli algens</u>	17(19.2)20	14(15.3)16	3.7-4.4	4.4-5		
<u>S. harveyanum</u>	20(23.5)25	14(15.0)16	2.2(3.0)3.8	3(3.7)4		
<u>Trachymene anisocarpa</u>	42(43.5)47	21(22.2)24	3.7(4.3)5	5(6.2)7		
<u>T. humilis</u>	31(33.2)36	16(18.6)21	1.6(2.3)3.1	4.4(5.7)6.9		

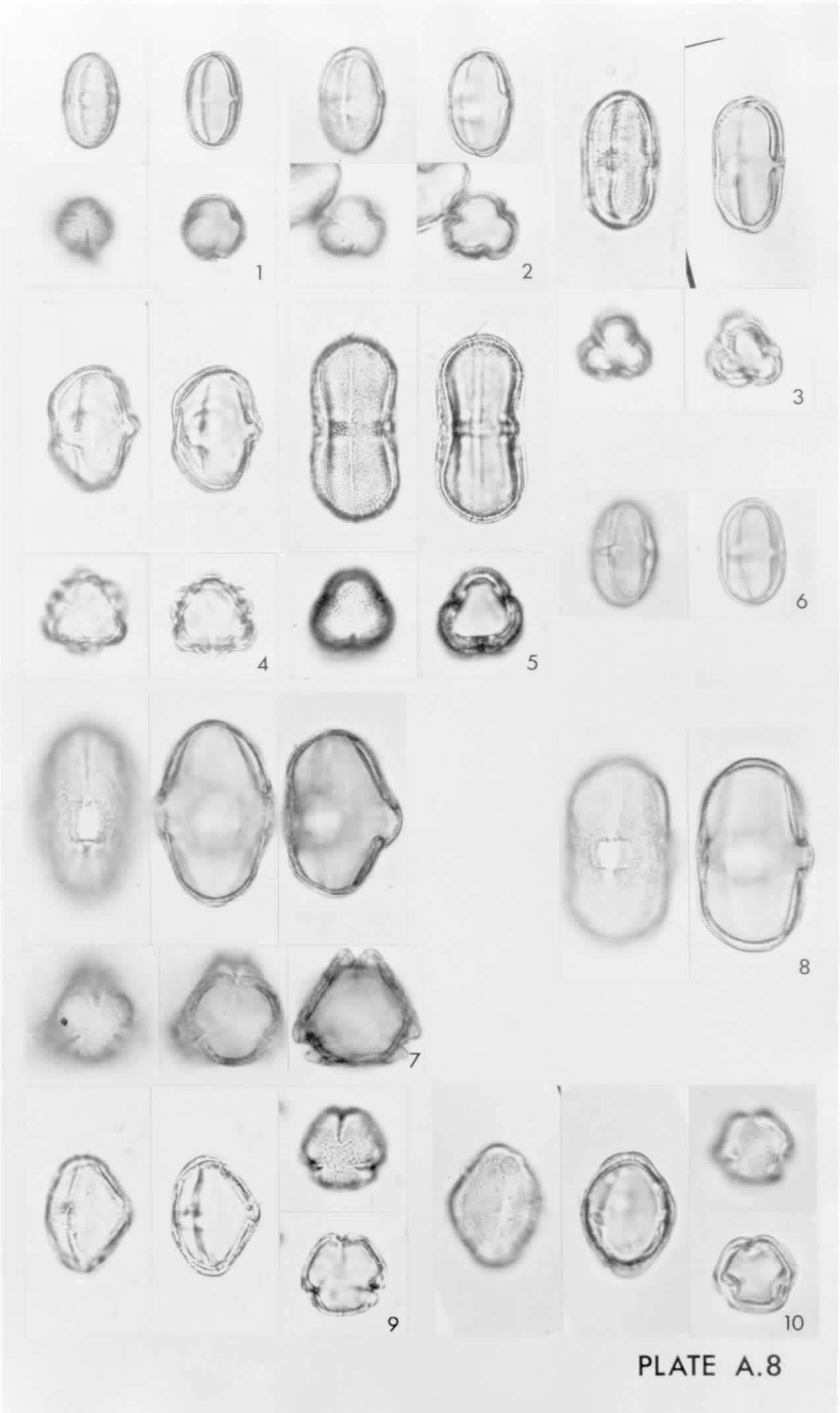


PLATE A.8

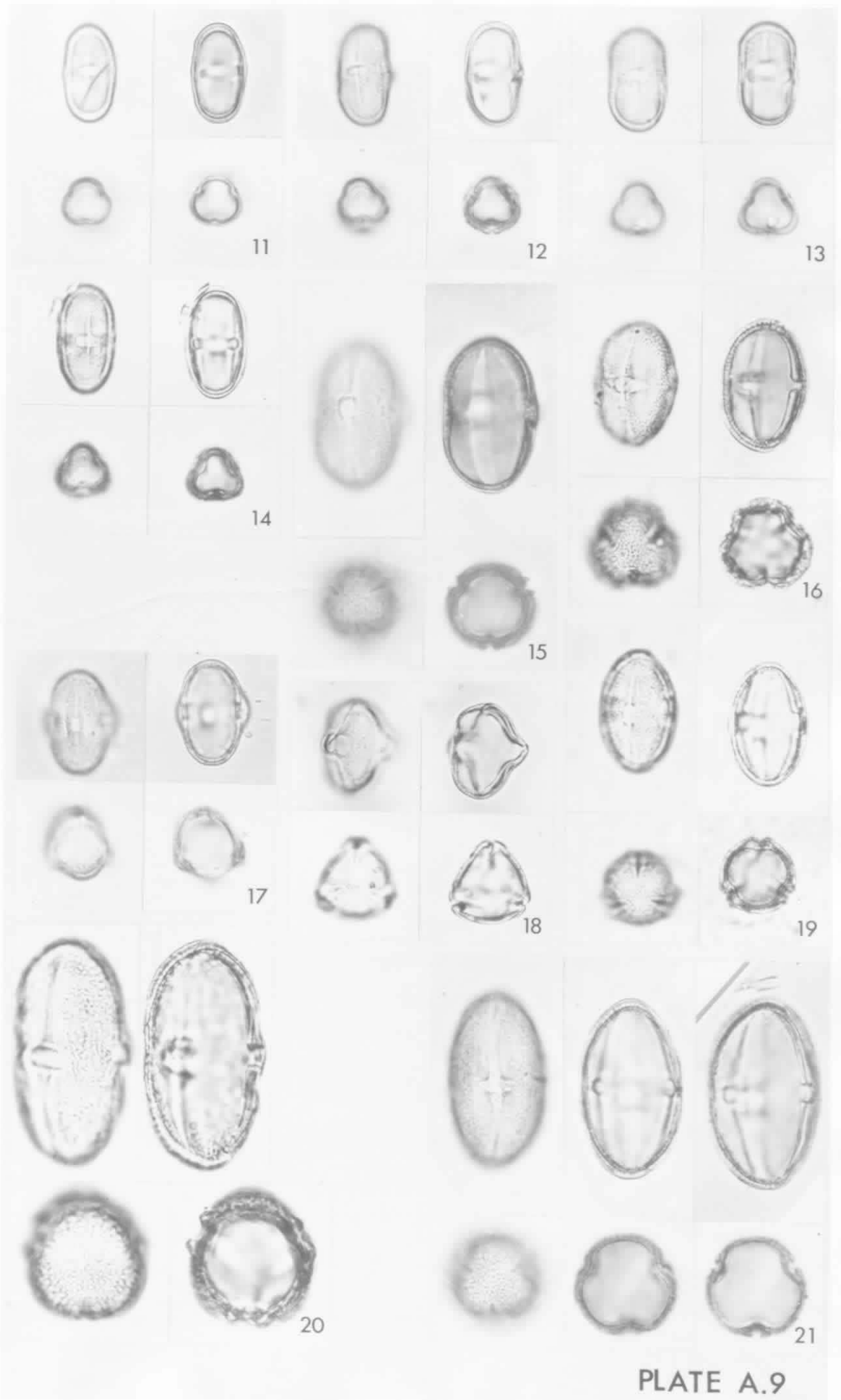


PLATE A.9

APPENDIX B

COMPUTER PROGRAMS

These were written in FORTRAN V for the Australian National University UNIVAC 1108 computer. They are partly self-documenting, but the following notes may be of assistance to future users.

Initial data input to the computer is in the form of standard 80 column punch cards. A numbered list of pollen and spore types is prepared with some blank categories to allow inclusion of additional taxa at a later date. For a pollen spectrum, the individual taxon counts are distributed, 20 taxa per card, according to the ordinal position of the taxa. Thus taxa 1-20 are recorded on the first card in 2013 format in the first 60 columns, taxa 21-40 on the second card and so on. The programs will accommodate any number of taxa in steps of 20, up to 160. The last 10 columns of each card may contain coded identification such as site, sample depth and slide number. the 80th column is usually reserved for serialisation of the cards comprising a spectrum.

POLGRP

This program accepts raw data and prints out a table of pollen counts. It then combines counts for individual taxa as directed by lists of taxon ordinal numbers. Each such list follows a code name assigned to the group. Up to 160 groups may be formed: the program checks that the number actually formed is in agreement with that specified in the control card which precedes the raw data. Pollen spectra may be combined in like manner by lists of spectra order numbers, each list following a code which is used to relabel the resulting spectra. Thus the order of spectra may be rearranged, depth assignments changed, and counts from different slides or depths combined. The reorganised data is output to

the printer or to a computer mass storage file, as directed on the control card, and also to a separate mass storage file in a card format similar to the raw data. The tables of Appendix D are an example of the final printed output of the program.

PLOTABS

This program converts pollen count data, in original format, or rearranged by POLGRP, into percentages. These are printed out in tabular form and also converted into a computer mass storage file of instructions for drawing a pollen diagram. This file is later transmitted, at the user's convenience, to a CALCOMP 560 plotter. Up to 24 individual taxa or groups of taxa can be handled in a single run: these groups are formed by the program according to a set of instruction cards input after the raw data. The pollen sum used as initial base for percentage calculations is the first group formed, but the program can be directed to use each of the groups in turn as base sum.

Operation of the program is directed by a control card which follows a card containing advice to be sent to the plotter operator. If absolute count data are required, an option in the control card directs the reading of a set of correction factors to be applied to the spectra. The printed output table then consists of the products of individual taxon proportions and the corresponding correction factors. These may be plotted according to a linear or logarithmic scale, as directed. The pollen diagrams in this thesis include all types of plot created by the program. A useful improvement would be to improve the packing of the diagrams, as there is at present too much waste space.

The program is derived from the PLNGPS program of Dodson (1972), but has been considerably modified to exclude the line printer plot routines and to encompass calculation and plotting of absolute as well as relative pollen frequency data, by Mr R. Crago of the Computer Section,

School Services, Research School of Pacific Studies, and the author.

CORRIE

This program was written for the specific purpose of effecting a correlation between Blue Lake cores 1 and 3, by comparison of pollen spectra. As described in Chapter 3 (Stratigraphy section), one core is designated the uppermost core. The first spectra and all subsequent ordinally equivalent spectra from both cores are compared and a mean dissimilarity measure calculated. The core designated as the lower one is then stepped down a spectrum, so that its first spectrum is compared with the second spectrum of the upper core, and so on. Mean dissimilarity is printed for each relative position of the cores, and a graph is drawn (figure 3.4).

The program accepts data in the same format as POLGRP output, so that selection of spore and pollen types for the correlation procedure is possible. Optionally, comparison may be made of absolute count data by reading in a list of correction factors to be applied to the spectra of both cores.

Since all spectra of both cores are used, samples must be equidistantly spaced at the same interval in both cores and each core must sample essentially the same stratigraphic sequence. Thus the program is not as widely applicable as the COREFIT program of Dodson (1972) in which three or fewer levels of one core are chosen for comparison. In the case of the Blue Lake cores, with rather uniform pollen spectra, it was felt that the procedure followed by CORRIE would give more sensitive results.

The dissimilarity measure used in the program is the information statistic. This arises from the concept of entropy and can be regarded as a measure of the disorder of a group (Williams *et al.*, 1966). In application to pollen spectra, each spectrum has an information content, I , defined by:

$$I = n \log (n) - \sum_{i=1}^m x_i \log (x_i)$$

where n = pollen sum total
 x = a taxon count
 m = the number of taxa in the sum
 i = taxon ordinal number

The information change due to fusion of two spectra into a single spectrum = $I_{1+2} - I_1 - I_2$, where I_{1+2} is the information content of the fused spectrum and I_1 and I_2 are the information contents of the individual spectra. If the two spectra are identical, the information change is zero: the statistic increases with increasing heterogeneity, and is thus a measure of the dissimilarity of the spectra.

POLZONE

This is a polythetic agglomerative classification program using a centroid strategy. The similarity measure used to judge between possible unions of spectra is the information statistic (above). The similarities between all pairs of spectra are calculated and the two most similar are fused. This composite spectrum replaces both its constituent members, and the calculation is repeated until a single group has been obtained. The program is thus similar in operation to that used by Dale and Walker (1970), but only stratigraphically adjacent spectra can be fused.

At each pass of the program the resulting groups are printed out with the value of the information statistic associated with the latest fusion. Finally, a zonation diagram is drawn which indicates the level of information statistic corresponding to each union of an individual spectrum with another spectrum or group of spectra.

Spectra are normalised with respect to each other by first dividing the count for each taxon of a spectrum by the total count for that spectrum: the information statistic is then calculated on these figures, in effect

probabilities. At each fusion, the program returns to the pre-normalisation step, so that fused spectra are treated in an equivalent way to individual spectra. This procedure is believed to eliminate group-size dependence on fusion of groups (Williams et al., 1970).

An option allows the zonation to be based on absolute count data, by input of a set of correction factors to be applied to the various spectra. In this case the information statistic is calculated on the basis of the corrected spectra and normalisation is not carried out.

Input format is the same as POLGRP output, so that selection of taxa for the zonation is possible. In addition, a control card field indicates to the program the number of taxa to be read in each spectrum, which allows some adjustment to be made.

Results of application of the program to Blue Lake data are indicated in figure B.1. The six highest fusions are given for calculations on the pollen sum taxa, and the pollen sum and extra-sum taxa, for both RPF and PDR data. With the RPF data, there is correspondence of three zone boundaries between the pollen sum and pollen sum plus extra-sum zonations. With the PDR data, all the six most important zone boundaries correspond in position although not in rank. There is evidently considerable variation between spectra in the levels 8 to 13 and 26 to 37 (this is confirmed by simple inter-spectrum comparisons).

As a compromise, zone boundaries which appeared in both RPF and PDR zonations were chosen. These correspond to major changes in total pollen deposition rate.

UNIT	SPECTRUM NO.	POLLEN SUM TAXA		POLLEN SUM+EXTRA SUM		
		RPF	PDR	RPF	TAXA	PDR
A	1					
	2					
	3					
	4					
	5					
	6					
	7					
	8			1		
	9	3				3
	10	2				
	11					
	12	6		6	6	5
	13					
	14					
	15					
	16					
	17					
	18					
	19					
	20					
	21					
	22					
	23					
	24					
	25					
	26	5		5		2
	27					
	28			3		6
	29				5	
	30					
	31	4			4	
	32					
	33			2		4
	34					
	35					
36			4	2	1	
C	37					
D	38					
E	39					
F	40			3		
G	41					
	42	1		1		
H	43					

FIG. B.1 POLZONE ZONATION OF BLUE LAKE
POLLEN SPECTRA

(Numbers, 1—, indicate importance of division, 1 highest.)

```
1  
2  
3  
4  
5  
6  
7  
8  
9  
10  
11 C PROGRAM POLGRP  
12 C THIS PROGRAM TAKES RAW SPECTRA AND FORMS COUNTS FOR GROUP  
13 C AND FOR GROUPS OF SPECTRA ( LEVELS OF POLLEN DIAGRAM)  
14 C
```

```
15 C INPUT FORMAT IS 20F3.0 FOR DATA, UNIT 1  
16 C OUTPUT FORMAT IS 20F3.0 FOR DATA, UNIT 24  
17 C
```

```
18 C FIRST DATA CARD: NOTAX,NOSPEC,NGRPS,NLEV,NOUT  
19 C NOTAX IS NO OF TAXA  
20 C NOSPEC IS NO OF TAXA  
21 C NGRPS IS NO OF GROUPS TO BE MADE  
22 C NLEV IS NO OF LEVELS OF SPECTRA TO BE MADE  
23 C NOUT IS LOGICAL UNIT NO FOR OUTPUT OF FINAL TABLE  
24 C RAW DATA SET CARDS FOLLOW  
25 C GROUP NAME CARDS ARE EACH FOLLOWED BY TAXON NO. CARDS  
26 C GROUP NAME CARD FORMAT (3X,A5)  
27 C TAXON NO. CARD FORMAT (I3)  
28 C A CARD WITH 200 IN COLS. 1-3 TERMINATES GROUP CARD SET  
29 C LEVEL NAME CARDS ARE EACH FOLLOWED BY SPECTRUM NO. CARDS  
30 C LEVEL NAME CARD FORMAT (3X,2A5)  
31 C SPECTRUM NO. CARD FORMAT (I3)  
32 C A CARD WITH 200 IN COLS. 1-3 TERMINATES LEVEL CARD SET  
33 C
```

```
34 C DIMENSION NAMGRP(160),LEVEL(60),LCONT(60)  
35 C INTEGER FDATA(160,60),DATA(160,60),GDATA(160,60)  
36 C EQUIVALENCE (DATA(1,1),GDATA(1,1))  
37 C
```

```
38 C READ CONTROL CARD  
39 C 400 READ(1,400)NOTAX,NOSPEC,NGRPS,NLEV,NOUT  
40 C
```

```
41 C 400 READ IN DATA  
42 C DO 30 J=1,NOSPEC  
43 C 100 READ(1,100) (DATA(I,J),I=1,NOTAX)  
44 C 30 READ(30,101) LEVEL(J),LCONT(J)  
45 C 101 FORMAT(70X,2A5)
```

```
46 C NS=1  
47 C NF=20  
48 C 40 IF(NOTAX=NF)41,41,1  
49 C PRINT OUT TABLE
```

```
50 C 41 NF=NOTAX  
51 C 1 WRITE ( 3,110)  
52 C 110 FORMAT(1H1,/,1X,'LEVEL TAXON NO.')
```

```
53 C WRITE ( 3,120) (I,I=NS,NF)  
54 C 120 FORMAT(14X,20(13,1X),/,)  
55 C DO 42 J=1,NOSPEC  
56 C 42 WRITE ( 3,130) (LEVEL(J),LCONT(J),(DATA(I,J),I=NS,NF))  
57 C 130 FORMAT(1X,2A5,3X,20(13,1X))  
58 C IF(NOTAX.EQ.NF) GO TO 50  
59 C NS=NS+20  
60 C NF=NF+20  
61  
62  
63  
64  
65
```

```

10      GO TO 40
11
12      50 I=1
13         DO 51 KJ=1,160
14            DO 51 KI=1,60
15            51 FDATA(KJ,KI)=0
16               WRITE ( 3,270)
17      C     READ GROUP NAME & COMPOSITION CARDS & FORM GROUPS
18      270 FORMAT(1H1)
19         READ( 1,200)NAMGRP(I)
20      200 FORMAT(3X,A5)
21         WRITE( 3,200)NAMGRP(I)
22      2 READ( 1,210) ICOLL
23      210 FORMAT(I3)
24         IF(ICOLL)91,5,3
25      3 IF(ICOLL.EQ.200) GO TO 7
26         WRITE( 3,260) ICOLL
27      260 FORMAT(7X,I3)
28         DO 4 J=1,NOSPEC
29      4 FDATA(I,J)=FDATA(I,J)+DATA(ICOLL,J)
30         GO TO 2
31      5 I=I+1
32         READ( 0,200)NAMGRP(I)
33         WRITE ( 3,200) NAMGRP(I)
34         GO TO 2
35      7 IF(NGRPS.NE.I) GO TO 90
36         J=1
37         DO 71 KJ=1,160
38            DO 71 KI=1,60
39      71 DATA(KJ,KI)=0
40         WRITE( 3,270)
41      C     READ LEVEL NAME & COMPOSITION CARDS & FORM GROUPS
42         READ( 1,201)LEVEL(J),LCONT(J)
43         WRITE( 3,201) LEVEL(J),LCONT(J)
44      201 FORMAT(3X,2A5)
45      8 READ ( 1,210) ICOLL
46         IF(ICOLL)91,11,9
47      9 IF(ICOLL.EQ.200) GO TO 13
48         WRITE( 3,260) ICOLL
49         DO 10 K=1,NGRPS
50      10 GDATA(K,J)=GDATA(K,J)+FDATA(K,ICOLL)
51         GO TO 8
52      11 J=J+1
53         READ( 0,201)LEVEL(J),LCONT(J)
54         WRITE ( 3,201) LEVEL(J),LCONT(J)
55         GO TO 8
56      13 IF(J.NE.NLEV) GO TO 90
57         NS=1
58         NF=15
59      14 IF(NGRPS=NF)15,15,16
60      15 NF=NGRPS

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11 C PRINT OUT FINAL TABLE OF GROUPED SPECTRA
12 16 WRITE(NOUT,300) (NAMGRP(I),I=NS,NF)
13 300 FORMAT(1H1,////////,19X,15(A5,1X),/,)
14 DO 18 J=1,NLEV
15 18 WRITE(NOUT,310) (LEVEL(J),LCONT(J),(GDATA(I,J),I=NS,NF))
16 310 FORMAT(7X,2A5,15(15,1X))
17 IF(NGRPS.EQ.NF) GO TO 17
18 NS=NS+15
19 NF=NF+15
20 GO TO 14
21 17 DO 20 J=1,NLEV
22 K=1
23 KK=20
24 C SEND DATA IN 2013 FORMAT TO LOGICAL UNIT 24
25 21 WRITE(24,80) (GDATA(I,J),I=K,KK),LEVEL(J),LCONT(J)
26 80 FORMAT(20I3,10X,2A5)
27 IF(NGRPS.LE.KK) GO TO 20
28 K=K+20
29 KK=KK+20
30 GO TO 21
31 20 CONTINUE
32 91 STOP
33 90 WRITE(3,240)
34 240 FORMAT(2X,'NO. OF GROUPS OR LEVELS INCORRECT AT READ-IN')
35 END
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C PROGRAM PLOTABS
C CALCULATES AND LISTS PERCENTAGES FOR MICROFOSSIL GROUPS RELATIVE
C TO ONE ANOTHER AND CREATES PLOTFILE (LDEV=9)
C MODIFIED BY I. RAINE 8/7/74
C INCLUDE LIB EB*ANUPL0T. IN MAP
C
C CARD WITH INSTRUCTIONS TO PLOTTER OPERATOR
C FIRST DATA CARD
C COL. 1-3 NO. OF DATA BATCHES (MAX = 80)
C COL. 4-6 NO. OF MICROFOSSIL TYPES (MAX = 160)
C COL. 7-8 NO. OF GRPS. TO FORM THE BASE SUM (THESE ARE ARR. 1ST)
C COL. 9-10 TOTAL NO. OF GPS. (< OR = 24)
C COL. 20 FOR RELATIVE COUNT PUT 0; FOR ABSOLUTE COUNT
C PUT 1 FOR LINEAR SCALE
C PUT 2 FOR LOG SCALE
C
C COL. 21-29 FACTOR TO GIVE CORRECT SIZE ABS PLOT IF JABS=1
C COL. 30-69 HEADING FOR SITE
C HEADINGS FOR GROUPS IN 2A6 FORMAT (COLS.1-12).
C BLANK CARD OR 'NOT USED' CARD IF <24 GROUPS
C DATA DECK IN 2D13 FORMAT (COLS.1-60), WITH DEPTHS IN 13 (COLS.78-80)
C CARDS CONTAINING LIST OF MICROFOSSIL TYPES FOR EACH GROUP:
C FORMAT 3X,MMMNNN WHERE MMM IS 1ST TAXON ORDINAL NO.
C NNN IS 2ND TAXON ORDINAL NO.
C X=1 IF TAXA MMM & NNN TO BE ADDED
C X=2 IF TAXA MMM TO NNN TO BE ADDED
C SEVERAL GROUPINGS MMMNNN MAY FOLLOW THE FIRST,
C WITHOUT SPACES, TO A MAXIMUM OF 11, ADDITIONAL
C CARDS MAY BE USED IF NECESSARY.
C CARDS WITH ABSOLUTE CORRECTION FACTORS IN E10.5 FORMAT,
C ONE PER CARD IN COLS.1-10, IN ORDER OF DEPTH INCREASING
C
C DIMENSION ISITE(12), LEV(80), NEV(80), PERC(25,80), CORR(80)
C DIMENSION NGP(2,25)
C COMMON MPLN(160), ILK
C COMMON LIST(160,80)
C DIMENSION X(320),Y(320)
C READ(1,1000) (ISITE(I), I=1,12)
1000 FORMAT(12A6)
C CALL PLOTG(9,2,100,0,0)
C CALL PLCMNT(72,ISITE)
C CALL PLOT(1.5,1.5,-3)
C READ CONTROL INFORMATION
C READ(1,10) NUM,NPLN, KNT, MANYGP, JABS, FACTOR, (ISITE(I), I=1,10)
10 FORMAT(13,13,12,12,9X,11,F9.0,10A4)
NABS=JABS
WRITE(3,11) (ISITE(I), I=1,10)
11 FORMAT(11H1,5HSITE,10A4,777)
C READ IN GROUP NAMES
DO 13 I=1,MANYGP
13 READ(1,14) (NGP(J,I), J=1,2 )
IF(MANYGP.EQ.24) GO TO 15
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11 READ(1,14) (NGP(J,25), J=1,2 )
12 14 FORMAT( 2A6)
13 C READ IN CORE DATA
14 15 DO 12 IBATCH=1,NUM
15 NNPLN=NPLN-20
16 MNPLN=NNPLN+1
17 READ(1,20)(LIST(I,IBATCH),I=1,NNPLN)
18 20 FORMAT(20I3)
19 READ(1,999)(LIST(I,IBATCH),I=MNPLN,NPLN),LEV(IBATCH),NEV(IBATCH)
20 999 FORMAT(20I3,12X,A4,1X,I3)
21 12 CONTINUE
22 C DO GROUPING AND PERCENTAGE CALCULATIONS
23 JUMP = 1
24 KOUNT = 0
25 25 KOUNT = KOUNT + 1
26 IF(KOUNT = KNT) 27,27,26
27 WRITE(3,28)
28 FORMAT(1H1,1X,21HFOR NEXT CALCULATIONS,/)
29 30 WRITE(3,31) (NGP(J,KOUNT), J=1,2 )
30 31 FORMAT(10X,27HTHE FOLLOWING = 100 PERCENT,5X,2A6 ,//)
31 GO TO (56,103), JUMP
32 56 DO 55 INIT =1,NUM
33 DO 55 IT=1,24
34 55 PERC(IT,INIT) = 0.0
35 DO 60 KA=1,MANYGP
36 CALL UTLY (NPLN)
37 DO 60 K=1,NUM
38 DO 60 L=1,ILK
39 NTT = MPLN(L)
40 60 PERC(KA,K) = PERC(KA,K) +FLOAT( LIST(NTT,K))
41 MANYGP=MANYGP
42 IF(MANYGP = 23) 42,42,103
43 MANYGP = MANYGP + 1
44 DO 43 KA=MANYGP,24
45 DO 43 K=1,2
46 43 NGP(K,KA) = NGP(K,25)
47 MANYGP = MANYGP - 1
48 103 DO 104 LOT=1,NUM
49 104 PERC(25,LOT)=PERC(KOUNT,LOT)
50 DO 102 LOT=1,NUM
51 DO 102 IPERC=1,24
52 IF(PERC(25,LOT)) 67,67,68
53 67 PERC(IPERC,LOT)=9999.0
54 GO TO 102
55 68 PERC(IPERC,LOT)=PERC(IPERC,LOT)/PERC(25,LOT)*100.0
56 102 CONTINUE
57 IF(JABS,NE,0) GO TO 39
58 803 IMANY = 1
59 JMANY = 6
60 C PRINT OUT PERCENTAGE TABLES
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11 38 WRITE(3,110) ((NGP(J,I), J=1,2 ), I=IMANY,JMANY)
12 110 FORMAT(10(/),2X,5HLEVEL,6( 8X,2A6 ),/)
13 WRITE(3,111)
14 111 FORMAT(2X,12A(1H=)/)
15 DO 115 LOT=1,NUM
16 115 WRITE(3,112) LEV(LOT), NEV(LOT), (PERC(N,LOT), N=IMANY,JMANY)
17 112 FORMAT(2X,A4,I3,1X,6(5X,F10.5,5X)/)
18 WRITE(3,111)
19 IF(JMANY - MANYGP) 41,41,39
20 41 IMANY = IMANY + 6
21 JMANY = JMANY + 6
22 GO TO 38
23 39 JUMP = 2
24 IF(JABS.EQ.0) GO TO 903
25 C READ IN CORRECTION FACTORS & CORRECT %'S
26 READ(1,800)(CORR(I),I=1,NUM)
27 800 FORMAT(F10.5)
28 DO 801 J=1,NUM
29 DO 801 I=1,NANYGP
30 801 PERC(I,J)=PERC(I,J)*CORR(J)/100.0
31 805 WRITE(3,802)
32 802 FORMAT(1H1,' ABSOLUTE COUNT FIGURES',///)
33 JABS=0
34 GO TO 803
35 C SET UP PERC FOR LINEAR SCALE ABSOLUTE COUNTS
36 903 NF=10
37 IF(NABS-1)904,904,906
38 DO 905 I=2,NANYGP
39 DO 905 J=1,NUM
40 905 PERC(I,J)=PERC(I,J)/FACTOR
41 GO TO 908
42 906 NF=1
43 DO 907 I=2,NANYGP
44 DO 907 J=1,NUM
45 IF(PERC(I,J)-1.0)907,907,909
46 909 PERC(I,J)=10.*ALOG10(PERC(I,J))
47 907 CONTINUE
48 C SET UP PLOTTER INSTRUCTION FILE
49 908 DO 900 I=2,NANYGP
50 NO=1
51 PMAX=0.
52 DO 901 J=1,NUM
53 IF(PERC(I,J).GT.PMAX)PMAX=PERC(I,J)
54 X(NO)=NEV(J)
55 Y(NO)=0.
56 X(NO+1)=X(NO)
57 Y(NO+1)=PERC(I,J)
58 X(NO+2)=X(NO)+0.02
59 Y(NO+2)=Y(NO+1)
60 X(NO+3)=X(NO+2)
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Y(NO+3)=0.  
NO=NO+4  
901 CONTINUE  
X(NO)=0.  
Y(NO)=0.  
X(NO+1)=100.  
Y(NO+1)=25.  
NO=NO-1  
LNTH=PMAX  
IF(PMAX.EQ.0.0)GO TO 900  
IF(LNTH.LT.4)LNTH=4  
LNTH=((LNTH/10)+1)  
ALNTH=FLOAT(LNTH*0.4)  
CALL PLOT(9.0,0.0,2)  
CALL PLOT(0.0,0.0,3)  
CALL PLOT(-0.3,0.0,-3)  
A=0.4  
DO 902 J=1, LNTH  
B=FLOAT(J*NF)  
C=A-0.07  
CALL SYMBOL(0.,A,0.07,13,90.,-1)  
CALL NUMBER(-0.07,C,0.07,B,90.0,-1)  
A=A+0.4  
902 CONTINUE  
CALL PLOT(0.0,0.0,3)  
CALL PLOT(0.0,ALNTH,2)  
CALL PLOT(0.0,0.0,3)  
CALL SYMBOL(-0.03,0.03,0.14,NGP(1,I),120.0,12)  
CALL PLOT(0.3,0.0,-3)  
CALL PLOT(0.0,ALNTH,2)  
CALL PLOT(0.0,0.0,3)  
CALL LINE(X,Y,NO,1,0,0)  
CALL PLOT(0.0,0.0,2)  
CALL PLOT(0.0,ALNTH+0.4,-2)  
900 CONTINUE  
GO TO 25  
26 CALL PLOT(0.0,0.0,999)  
GROUPING SUBROUTINE  
SUBROUTINE UTLY (NPLN)  
DIMENSION LOT1(11), IA(11), LOT2(11)  
COMMON MPLN(160),ILK  
KNUT = 1  
20 READ(1,1) (LOT1(I), IA(I), LOT2(I), I=1,11)  
1 FORMAT(3X,11(I3,11,13))  
II = 1  
30 IF(LOT1(II)) 9,9,4  
4 IF(IA(II).EQ.2) GO TO 5  
MPLN(KNUT) = LOT1(II)  
KNUT = KNUT + 1  
MPLN(KNUT) = LOT2(II)
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11 )      KNUT = KNUT + 1
12 )      GO TO 8
13 )      5 MPLN(KNUT) = LOT1(II)
14 )      6 IF(LOT2(II) = LOT1(II))7, 7,50
15 )      50 LOT1(II) = LOT1(II) + 1
16 )      KNUT = KNUT + 1
17 )      MPLN(KNUT) = LOT1(II)
18 )      GO TO 6
19 )      7 KNUT = KNUT + 1
20 )      8 II = II + 1
21 )      IF(II = 11) 30,30,20
22 )      9 ILK = KNUT - 1
23 )      RETURN
24 )      END
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11 C PROGRAM CORRIE
12 C CONTROL CARD FORMAT (NPLN,LEVA,LEVB,ICUT), FORMAT OPEN
13 C NPLN= NO OF POLLEN TAXA TO BE READ FROM CARDS
14 C LEVA= NO OF LEVELS IN CORE A (FIXED CORE)
15 C LEVB= NO OF LEVELS IN CORE B (MOVABLE CORE)
16 C ICUT= NO OF TAXA TO BE CONSIDERED IN COMPARISON
17 C DATA CARDS IN (2DF3.0) FORMAT
18 C CARD WITH 1 OR 0 IN COLUMN 1: 1= DO ABSOLUTE COUNT COMPARISON
19 C 0= DO RELATIVE COUNT COMPARISON
20 C CARDS WITH CORRECTION FACTORS FOR CORE A, IF NECESSARY
21 C CARDS WITH CORRECTION FACTORS FOR CORE B, IF NECESSARY
22 C
23 C DIMENSION A(160,30),B(160,30),TOTI(60),CORA(30),CORB(30)
24 C READ CONTROL CARD
25 C READ(1,100) NPLN,LEVA,LEVB,ICUT
26 C 100 FORMAT( )
27 C READ DATA CARDS, CORE A BEFORE CORE B
28 C READ(1,101)((A(I,J),I=1,NPLN),J=1,LEVA)
29 C READ(1,101)((B(I,J),I=1,NPLN),J=1,LEVB)
30 C 101 FORMAT(2DF3.0)
31 C WRITE(3,102)
32 C 102 FORMAT(2X,'SHALL I DO ABSOLUTE COUNT COMPARISON ?')
33 C READ(1,103)N
34 C 103 FORMAT(11)
35 C IF(N.EQ.1)GO TO 7
36 C READ CORRECTION FACTORS
37 C READ(1,100)(CORA(K),K=1,LEVA)
38 C READ(1,100)(CORB(K),K=1,LEVB)
39 C GO TO 9
40 C 7 DO 8 K=1,30
41 C CORA(K)=1.
42 C 8 CORB(K)=1.
43 C 9 DO 1 J=1,LEVA
44 C SUMA=0.
45 C DO 2 I=1,ICUT
46 C 2 SUMA=SUMA+A(I,J)
47 C DO 3 I=1,NPLN
48 C 3 A(I,J)=A(I,J)*CORA(J)/SUMA
49 C 1 CONTINUE
50 C DO 4 J=1,LEVB
51 C SUMB=0.
52 C DO 5 I=1,ICUT
53 C 5 SUMB=SUMB+B(I,J)
54 C DO 6 I=1,NPLN
55 C 6 B(I,J)=B(I,J)*CORB(J)/SUMB
56 C 4 CONTINUE
57 C N=1
58 C IF(LEVA.LE.LEVB) LIM=LEVA
59 C 13 IF(LEVA.GT.LEVB) LIM=LEVB+N-1
60 C IF(LIM.GT.LEVA) LIM=LEVA
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11     TOTI(N)=0.
12     DO 10 J=N,LIM
13     K=J-N+1
14     AI=0.
15     BI=0.
16     FI=0.
17     SUMA=0.
18     SUMB=0.
19     DO 11 I=1,NPLN
20     SUMA=SUMA+A(I,J)
21     SUMB=SUMB+B(I,K)
22     AI=AI+RINF(A(I,J))
23     BI=BI+RINF(B(I,K))
24     11 FI=FI+RINF(A(I,J)+B(I,K))
25     10 TOTI(N)=RINF(SUMA+SUMB)-FI+AI-RINF(SUMA)+BI-RINF(SUMB)+TOTI(N)
26     TOTI(N)=TOTI(N)/(LIM-N+1)
27     IF(N.EQ.LEVA) GO TO 12
28     N=N+1
29     GO TO 13
30     12 WRITE(3,104)
31     104 FORMAT(IX,'FIRST LEVEL OF FIRST SEQUENCE MATCHED:',6X,'DISSIMILARI
32     CTY:')
33     WRITE(3,105) (N,TOTI(N),N=1,LEVA)
34     105 FORMAT(40X,I3,17X,E10.4)
35     DO 14 K=1,N
36     TOTI(K+N)=TOTI(K)
37     14 TOTI(K)=K
38     CALL PLOTLP(1,TOTI,N,2,N,,TRUE,, '*')
39     FUNCTION RINF(ARG)
40     IF(ARG)1,1,2
41     1 RINF=0.
42     RETURN
43     2 RINF=ARG*ALOG(ARG)
44     RETURN
45     END
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11 C PROGRAM POLZONE
12 C IN EB*ANULIB1.PLOTLP AFTER MAP
13 C CONTROL CARD (N,M,JABS) IN FREE FORMAT
14 C N IS NO. OF LEVELS
15 C M IS NO. OF TAXA CONSIDERED
16 C JABS=0 FOR RELATIVE FIGURES FOR ABSOLUTE COUNT ZONING SET JA
17 C POSITIVE INTEGER
18 C DATA CARDS FOLLOW IN 2013 FORMAT
19 C IF DESIRED, CORRECTION FACTORS IN (E10.5) FORMAT
20 DIMENSION D(50,160),AID(50),AIE(50),AIFUS(50),A(102)
21 DIMENSION NSEQ(50),CORR(50),SUM(50)
22 C READ IN CONTROL INFORMATION & CHECK PROBLEM SIZE
23 READ(1,130) N,M,JABS
24 130 FORMAT(
25 IF((M.LE.160).OR.(N.LE.50)) GO TO 15
26 WRITE (3,131)
27 131 FORMAT(2X,'PROBLEM TOO LARGE')
28 STOP
29 15 NP=N+1
30 C INITIALISE ARRAYS FOR PLOTLP
31 DO 1 I=1,NP
32 1 A(I)=FLOAT(I)-0.5
33 NP2=NP*2-1
34 NOLD=N
35 NNEW=N-1
36 DO 2 I=1,N
37 2 NSEQ(I)=I
38 C READ IN DATA
39 DO 3 I=1,N
40 3 READ ( 1,100) (D(I,J),J=1,M)
41 100 FORMAT(20F3.0)
42 C INFORMATION STATISTIC BASED ON ABSOLUTE COUNT DATA
43 IF(JABS.EQ.0) GO TO 13
44 READ(1,81) (CORR(I),I=1,N)
45 81 FORMAT(E10.5)
46 DO 82 I=1,N
47 DO 83 J=1,M
48 83 D(I,J)=D(I,J)*CORR(I)
49 82 CONTINUE
50 84 IF(JABS.EQ.0) GO TO 13
51 NO=N-NNEW
52 DO 64 I=1,NOLD
53 NN=NSEQ(I)
54 SUMT=0.
55 AID(I)=0.
56 DO 61 J=1,M
57 61 SUMT=SUMT+D(NN,J)
58 DO 62 J=1,M
59 62 AID(I)=AID(I)+RINF(D(NN,J))
60 AID(I)=RINF(SUMT)-AID(I)
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64 CONTINUE
DO 66 I=1,NNEW
  NN=NSEQ(I)
  NNN=NSEQ(I+1)
  AIE(I)=0.
  SUMT=0.
DO 65 J=1,M
165 SUMT=SUMT+D(NN,J)+D(NNN,J)
DO 92 J=1,M
192 AIE(I)=AIE(I)+RINF(D(NN,J)+D(NNN,J))
  AIE(I)=RINF(SUMT)-AIE(I)
66 CONTINUE
GO TO 67
C INFORMATION STATISTIC BASED ON PROBABILITIES
13 NO=N-NNEW
DO 4 I=1,NOLD
  NN=NSEQ(I)
  SUM(I)=0.
  AID(I)=0.
DO 51 J=1,M
151 SUM(I)=SUM(I)+D(NN,J)
DO 52 J=1,M
152 AID(I)=AID(I)-RINF(D(NN,J)/SUM(I))
4 CONTINUE
DO 6 I=1,NNEW
  NN=NSEQ(I)
  NNN=NSEQ(I+1)
  AIE(I)=0.
DO 72 J=1,M
172 AIE(I)=AIE(I)+RINF(D(NN,J)/SUM(I)+D(NNN,J)/SUM(I+1))
  AIE(I)=RINF(2.)-AIE(I)
6 CONTINUE
C CALCULATE INFORMATION GAIN ON FUSION
67 DO 8 J=1,NNEW
  AIFUS(J)=AIE(J)-AID(J)-AID(J+1)
C PRINT DELTA I FOR INITIAL PAIRS OF SPECTRA
IF(NOLD.EQ.N) WRITE(3,140) (J,AIFUS(J),J=1,NNEW)
140 FORMAT(2X,' COMPARISONS BETWEEN LEVELS: DELTA I VALUES FOR FUSIONS
$ BETWEEN LEVEL N AND NEXT LEVEL',/,3X,'N',6X,'DELTA I',/,
$(2X,I2,6X,E10.4))
C FIND MINIMUM INFORMATION GAIN
AIMIN=AIFUS(1)
IMIN=1
DO 10 J=1,NNEW
  IF(AIMIN-AIFUS(J)) 10,10,14
14 AIMIN=AIFUS(J)
  IMIN=J
10 CONTINUE
IM=IMIN+1
NOW=NSEQ(IMIN)
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11     NEXT=NSEQ(IM)
12     IF(NOLD.EQ.N) WRITE(3,160)
13 160  FORMAT(1H1)
14     IF(IMIN.EQ.NNEW) GO TO 16
15     IF(NNEW.EQ.IM)NNEW1=NNEW-1
16     NNEW1=NNEW
17     DO 9 J=IM,NNEW1
18     IF((AIFUS(J)-AIMIN).GT.1E-6) GO TO 9
19     WRITE(3,120) NOW,NEXT,NSEQ(J),NSEQ(J+1)
20 120  FORMAT(2X,'FOR NEXT FUSION, AMBIGUITY RESOLVED BY FUSING
21     $',I2,' AND ',I2,' RATHER THAN ',I2,' AND ',I2)
22     9  CONTINUE
23     C  ENTER PLOT ARRAY
24     16  A(NP+NEXT)=AIMIN
25     C  FUSE LEVELS WITH MINIMUM INFORMATION GAIN ON FUSION
26     DO 12 J=1,M
27     12  D(NOW,J)=D(NOW,J)+D(NEXT,J)
28     DO 11 I=IMIN,NNEW
29     11  NSEQ(I+1)=NSEQ(I+2)
30     C  PRINT RESULT
31     WRITE(3,110) NO,AIMIN,(NSEQ(I),I=1,NNEW)
32 110  FORMAT(2X,'FUSION NO.',I3,' ; INFORMATION GAIN ',E10.4,'
33     $SEQUENCE REMAINING: ',/,(20(IX,I3,IX)))
34     C  RESET PASS PARAMETERS AND TEST FOR LAST PASS COMPLETED
35     NOLD=NNEW
36     NNEW=NNEW-1
37     IF(NNEW.EQ.D) GO TO 30
38     GO TO 84
39     30  WRITE(3,150)
40 150  FORMAT(1H1)
41     CALL PLOTLP(1,A,NP,2,NP2,,TRUE,,*)
42     FUNCTION RINF(ARG)
43     IF(ARG) 1,1,2
44     1  RINF=0
45     RETURN
46     2  RINF=ARG*ALOG(ARG)
47     RETURN
48     END
49
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APPENDIX C

VEGETATION STUDY DATA

Vegetation study plot locations are indicated in the vegetation map, fig. 1.4. Each plot, a 30m x 30m quadrat was chosen by a two-step subjective process. First, an area of about 300 metres square was chosen on the map of Eucalyptus associations presented by Morland (1959). On arrival in this area, the plot was chosen in an apparently typical area without obvious disturbance. Where great differences in structure were evident, two plots were located. The method of plot selection is subject to many of the criticisms of subjective bias referred to by, for example, Greig-Smith (1957), but it was felt that the nature of the terrain and the time available precluded random or regular sampling. Since the primary aims were to reconnoitre the altitudinal distribution and relative importance of pollen-producing plants, and not to make quantitative estimates of cover or detailed phytosociological investigations, the method may suffice.

Plot characteristics are tabulated in Table C.1. Altitudes were derived from the Australian Government 1:100000 series map Kosciusko. Aspect was measured in the field with a hand-held compass, while slope and canopy height were measured with a Haga instrument. Soil pH at 5 cm depth was measured with a buffered chemical colour indicator; soil and rock type were extrapolated from nearby road sections. The codes under soil type in table C.1 stand for the soil groups of Stephens (1962): RE = red earth, YE = yellow earth, AH = alpine humus soil, SK = Skeletal. Shade value, measured at 1.5m above the ground, was the difference in light value (LV) from that simultaneously obtaining in open areas nearby, as determined by a photographic exposure meter. A value of 1 corresponds to a loss of 50% of available light, 2 a loss of 75%, 3 a loss of 87½% and so on.

In each plot, percentage cover of canopy trees, understorey trees and shrubs, and ground layer was estimated. These divisions correspond respectively to the following life-form classes of Raunkiaer (see Appendix D): epiphytes plus mega- and meso- phanerophytes; micro- and nanophanerophytes; chamaephytes, hemicryptophytes, geophytes and therophytes. Since survey was carried out in winter, therophytes and some geophytes were poorly represented, but these are not an important component of

this vegetation. First, total cover for each stratum was estimated as the percentage of ground covered by the vertically projected areas of imaginary envelopes closely surrounding each plant. This does not correspond to the cover measurements of projected foliage area produced by point-quadrat methods (Greig-Smith, 1957), but is rather a measure of canopy. Following this, plant species were scored according to the proportion of this cover that they contributed using the following scale:

- 5 = more than 75%
- 4 = 50-75%
- 3 = 25-50%
- 2 = 5-25%
- 1 = less than 5%, but numerous
- + = sparse

This was accomplished by 'cruising' through the plot to gain an overall impression. In this way both canopy and ground layer plants could be described by the same method.

Eucalyptus species, difficult to determine from herbarium material alone (and this difficult to obtain) were identified by reference to the descriptions and Key of Hall et al. (1970). Other unknown plants were collected and submitted, with an A.N.U. collection number, to the CSIRO herbarium, Canberra. Final responsibility for identifications must, however, rest with the author. The works of Burbidge & Gray (1970) and Willis (1962, 1972) proved of great assistance: nomenclature follows the latter author.

Results are presented in Table C.2, in which plots are arranged according to altitude, and plant genera alphabetically under each structural heading. This data is discussed, in context, in Chapter 1.

TABLE C.1 Vegetation Plot Characteristics

Site no.	Alt. (m)	Aspect	Slope %	Soil pH 5 cm	Soil type	Rock type	Canopy ht. (m)	Shade value
1	520	NE	60	5.5	RE	Granite	24	2.5
2	520	NW	10	6	RE	Granite	39	1.5
3	520	SW	30	5.5	sk RE	Metamorphic	21	2
4	550	SE	30	5.5	RE	Granite	33	2
5	565	N	35	6	RE	Granite	26	1
6	580	N	40	6	RE	Granite	20	1
7	615	W	15	5	RE	Granite	30	1.5
8	715	NW	30	6	RE	Granite	33	2
9	760	S	30	5.5	RE	Metamorphic	20	3.5
10	1005	NW	35	6	YE	Metamorphic	27	1.5
11	1005	SE	70	6	YE	Metamorphic	15	1
12	1140	NW	40	5.5	RE	Metamorphic	46	1.5
13	1170	SE	80	5.5	sk RE	Metamorphic	30	1.5
14	1180	W	20	6	RE	Granite	14	1
15	1200	NW	65	6	sk RE	Metamorphic	30	2
16	1235	NE	70	5.5	RE	Metamorphic	34	2
17	1400	SE	80	6	sk RE	Granite	7	1
18	1400	SE	80	6	sk RE	Granite	9	1.5
19	1430	SW	55	6	RE	Metamorphic	23	1
20	1520	NW	30	5.5	RE	Granite	20	1
21	1560	NE	50	5.3	AH	Granite	7	2
22	1700	NW	25	4.3	AH	Granite	8	1

Table C.2

Vegetation Plot Species Cover

Coll. No. A.N.U.	SITE ALTITUDE (m) ASPECT	1 NE	2 NW	3 SW	4 SE	5 N	6 N	7 W	8 NW	9 S	10 NW	11 SE	12 NW	13 SE	14 W	15 NW	16 NE	17 SE	18 SE	19 SW	20 NW	21 NE	22 NW			
<u>CANOPY EMERGENTS</u>																										
	Eucalyptus viminalis (Myrt.)	COVER									15															
											5															
<u>CANOPY</u>																										
		COVER																								
10424	Acacia dealbata (Mim.)	60	35	50	50	50	30	50	35	70	55	10	30	40	60	70	70	15	60	50	70	30	50			
	Amyema sp. (Loranth.)	+																								
	Eucalyptus bicostata (Myrt.)					2	+															2				
	dalrympleana (Myrt.)											4	3	2	+	3						5	2			
	delegatensis (Myrt.)													5						5						
	dives (Myrt.)											4			4											
	fastigata (Myrt.)													4												
	maculosa (Myrt.)	+																								
10472	mannifera (Myrt.)						+	1																		
	pauciflora (Myrt.)													4						4	5	5				
	perriniana (Myrt.)															2	1									
	radiata (Myrt.)	5	4	5	5	4	2	5																		
	viminalis (Myrt.)			3	+			1	2	2											5					
<u>UNDERSTOREY TREES AND SHRUBS</u>																										
		COVER																								
	Acacia dallachiana (Mim.)	20	40	30	40	60	30	80	95	100	60	70	60	60	30	10	5	70	80	30	60	90	30			
10397	dealbata (Mim.)						1			2	1	4			2						5					
10427	implexa (Mim.)	+	+																							
10459	kettlewelliae (Mim.)				2																					
	melanoxylon (Mim.)			+																	+					
10487	obliquinervia (Mim.)																	2	1							
	siculiformis (Mim.)																			1	+					
	Atherosperma moschatum (Monim.)													2												
	Raekaea gunniana (Myrt.)																									
	utilis (Myrt.)																					1	+			
	Redfordia salicina (Ast.)						+			2			+													
10405	Billardiera scandens (Pittos.)							+																		
	Bossiaea foliosa (Papil.)													2						1	5	5	4	5		
	Callistemon sieberi (Myrt.)																									
10403	Cassinia aculeata (Ast.)	+	+			+			1																	
	Clematis aristata (Ran.)													+												
10447	Comesperma volubile (Papil.)					+																				
10433	Coprosma hirtella (Rub.)													1	+	1			3	2			3	+		
10435	quadrifida (Rub.)			1	+	1															+	+				
	Correa lawrenciana (Rut.)													+	+											
10423	Daviesia latifolia (Papil.)	+																								
	mimosoides (Papil.)													2	4	2			+	1			+			
	ulicifolia (Papil.)																	+	3							
	Dianella tasmanica (Liliac.)													1												
	Dicksonia antarctica (Dicks.)																	1	+							
	Drimys lanceolata (Wint.)																	1	+							
	xerophila (Wint.)																			5	2	+	2	+		
	Eriostemon myoporoides (Myop.)																	+								

Table C.2 (continued) .

Coll. No. A.N.U.	SITE ALTITUDE (m) ASPECT	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
		520 NE	520 NW	520 SW	550 SE	565 N	580 N	615 W	715 NW	760 S	1005 NW	1005 SE	1140 NW	1170 SE	1180 W	1200 NW	1235 NE	1400 SE	1400 SE	1430 SW	1520 NW	1560 NE	1700 NW
<u>GROUND LAYER</u> (cont'd)																							
10401	<i>Hypericum japonicum</i> (Gutt.) <i>gramineum</i> (Gutt.)	+		+	2		1	1	+		+				+						+		
10462	<i>Hypochoeris radicata</i> (Ast.)	+		+										1				+				+	
10412	<i>Lomandra longifolia</i> (Xanth.)	1		+	+		+																
10421	<i>Lomatia myricoides</i> (Prot.) <i>Lycopodium fastigiatum</i> (Lycop.)	+																	+			+	
10399	<i>Mentha laxiflora</i> (Lamiac.)								+														
10425	<i>Microlaena</i> sp. (Poa.) <i>Myosotis australis</i> (Borag.) <i>Olearia phlogopappa</i> (Ast.)		1		1	+		1															
10457	<i>Onopordum</i> sp. (Ast.) <i>Oreomyrrhis eriopoda</i> (Ap.)		+																		+		+
10453	<i>Oxalis corniculata</i> (Oxalid.)		+																				
10419	<i>Oxylobium procumbens</i> (Papil.) <i>ellipticum</i> (Papil.) <i>Parahebe derwentiana</i> (Scroph.)	+					1									2			+			1	2
10477	<i>Persoonia chamaepeuce</i> (Ast.)						+															+	
10417	<i>confertiflora</i> (Ast.) <i>Picris hieracioides</i> (Ast.)	+																		+			
10391	<i>Pimelea axiflora</i> (Thym.)									+													
10454	<i>Plantago</i> sp. (Plantag.)		+								+												
10390	<i>Platylobium formosum</i> (Papil.)			1																			
10470	<i>Poa australis</i> (spp. agg.) (Poa.) <i>helmsii</i> (Poa.)	2		4	3	3	5	1			+	5		4	5	4	3	+			5	3	5
10418	Poaceae indet.	+	4	+	1																		
	<i>Podolepis robusta</i> (Ast.) <i>Polystichum proliferum</i> (Asp.) <i>Poranthera microphylla</i> (Euph.) <i>Pratia purpurascens</i> (Campan.)		+	+						4	2		3		2			1	1	+	+		+
10485	<i>Prunella vulgaris</i> (Lamiac.)		+																			+	
10463	<i>Pterostylis</i> sp. (Orchid.)			+																			
10404	<i>Pteridium esculentum</i> (Pterid.)									1						2							
10406	<i>Pultenaea juniperina</i> (Papil.) <i>Ranunculus graniticola</i> (Ranun.) <i>plebeius</i> (Ranun.)					+	+	+								2							+
10445	sp. (Ranun.)		1		+			+							+	+							
10450	<i>Rubus parvifolius</i> (Ros.) <i>Rumex acetosella</i> (Polygn.) <i>Scleranthus biflorus</i> (Cary.) <i>Senecio gunnii</i> (Ast.) <i>linearifolius</i> (Ast.) <i>Seseli harveyanum</i> (Ap.)	+	+	+			+		+		+			1		1			+		+		+
10408	<i>Stackhousia monogyna</i> (Stack.) <i>Stellaria angustifolia</i> (Cary.)						+	+														+	
10392	<i>pungens</i> (Cary.)		2	+						2		+		1	+	2			+	+	1	+	1
10481	c.f. <i>flaccida</i> (Cary.)									2													

Table C.2 (continued).

Coll. No. A.N.U.	SITE ALTITUDE (m) ASPECT	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
		520 NE	520 NW	520 SW	550 SE	565 N	580 N	615 W	715 NW	760 S	1005 NW	1005 SE	1140 NW	1170 SE	1180 W	1200 N	1235 NE	1400 SE	1400 SE	1430 SW	1520 NW	1560 NE	1700 NW
<u>GROUND LAYER (cont'd)</u>																							
10422	<i>Stylidium graminifolium</i> (Styl.)	+		+								+			2			+				+	
	<i>Taraxacum officinale</i> (Ast.)																						+
10478	<i>Tetradlea aff. ericifolia</i> (Trem.)						+																+
	<i>Themeda australis</i> (Poa.)														+						+		+
10436	<i>Tieghemopanax sambucifolius</i> (Aral.)				+						1		+								+		+
	<i>Trifolium repens</i> (Papil.)																						
	<i>Urtica incisa</i> (Urtic.)									1													
10413	<i>Veronica calycina</i> (Scroph.)		1	+				1						1	1								+
10416	<i>Viola betonicifolia</i> (Viol.)	1													+	+							
10396	<i>hederacea</i> (Viol.)	1	+	2	2	1	+	4	5		3	1											
10415	<i>Wahlenbergia stricta</i> (Campan.)							+															+
	<i>sp. cf. communis</i> (Campan.)																						+
	Bryophyta							1		+									2	2			
10490	Unknown		+																				

APPENDIX D

POLLEN DATA

All original pollen counts, before calculation of relative or absolute frequencies, are recorded in table D.2-D.9.

Each pollen or spore taxon in the computer print-out tables (prepared by POLGRP) is assigned a mnemonic code-name which appears at the head of each table. These code-names may be deciphered by reference to table D.1., which lists the corresponding pollen taxon of Key-1 or Key-2 of Appendix A, as well as life-form and brief ecological information. Some taxa are divided into several size classes, e.g. Poaceae, which are also indicated in table D.1. The order follows that of the Syllabus der Pflanzenfamilien of Engler and Prantl (1924). Pollen from 62 families has been recognised (174 families of Pteridophyta and Spermaphyta are listed for Victoria in Willis (1962, 1972)).

The life-form classification in table D.1 is that of Raunkiaer (1934). Symbols and their meanings are as follows:

- E EPIPHYTES (vines, parasites and epiphytic ferns)
- MM MEGA- AND MESOPHANEROPHYTES : Perennating buds or shoot apices borne on aerial shoots more than 8 m above the ground (trees)
- M MICROPHANEROPHYTES : Perennating buds 2-8 m above the ground (tall shrubs, small trees)
- N NANOPHANEROPHYTES : Perennating buds less than 2 m above the ground (shrubs)
- Ch CHAMAEPHYTES : Perennating buds or shoot apices very close to the ground (shrubs)
- H HEMICRYPTOPHYTES : Perennating buds at ground level or in litter (herbs, ferns)
- G GEOPHYTES : Perennating buds in rhizome, bulb or tuber (herbs, ferns)
- HH HELOPHYTES & HYDROPHYTES : Perennating buds below water-level in soil, mud or water (swamp and aquatic herbs)
- Th THEROPHYTES : Perennating bud in seed (annual herbs)

Each slide counted is given a separate row in the tables D.2-D.9, and is identified by a code at the left-hand side of the table. This code refers to the page preceding each table where, for example, true sample depths, total pollen count, etc. are tabulated.

CODE	POLLEN TAXON	LIFE FORM	KNOWN ECOLOGY AND DISTRIBUTION
TYPHA	Typhaceae - Sparganiaceae	HH	Rooted in solid substrate of open-water situations below 1000 m.
TRIGL	<u>Triglochin</u> (Juncaginaceae)	HH	Similar to above.
POA 1	Poaceae, Diameter D < 20 μ	H,G,TH,HH	Grasslands, alpine herbfield, understorey of savannah woodland, mallee and sclerophyll forest at all elevations.
POA 2	" D 20 - 25 μ		
POA 3	" D 25 - 30 μ		
POA 4	" D 30 - 35 μ		
POA 5	" D > 35 μ		
POA 6	" D > 40 μ		
POA A	" not measured		
CYPER	Cyperaceae	H,G,HH	Mainly fens : on wetter sites at all elevations.
RESTI	Restionaceae	HH	Wet sites, mainly at higher elevations.
XYRIS	<u>Xyris</u> (Xyridaceae)	G	Swampy heaths of coastal areas : not in mountains.
ASPHO	Liliaceae subf. Asphodeloidiae	G	Widespread mainly in forests : some alpine genera, e.g. <u>Arthropodium</u>
DIANE	<u>Dianella</u> (Lil.)	G	Robust plants of sclerophyll forest understorey.
ASTEL	<u>Astelia</u> (Lil.)	H	Seepage areas above 1,500 m, forming sward.
CASUA	<u>Casuarina</u> (Casuarinaceae)	MM, M,N	Trees of river banks and rocky outcrops at lower elevations: shrubs on sandstone areas and western plains.
URTIC	Urticaceae	H,Th	Herbs of shady places in forests.
GREVI	<u>Grevillea</u> sim. (Proteaceae)	Ch,N	Shrubs in heath and forest at all elevations.
HAKA	<u>Hakea</u> (Prot.)	M,N	Shrubs in drier heath and forest, lower elevations.
BANKS	<u>Banksia marginata</u> comp. (Prot.)	M	Trees of dry sclerophyll forest and woodland at lower elevations.
LOMAT	<u>Lomatia</u> (Prot.)	N	Shrubs of wet sclerophyll forest.
EXOCA	<u>Exocarpos</u> (Santalaceae)	M	Root-parasitic trees apparently increased in frequency by disturbance: forests and woodland, lower elevations.
AMYEM	<u>Amyema</u> (Loranthaceae)	E	Parasites of <u>Eucalyptus</u> and <u>Casuarina</u> spp. on tablelands.
RUMEX	<u>Rumex</u> (Polygonaceae)	H	<u>R. brownii</u> native, lower elevations: other spp. naturalised aliens, disturbed sites, all elevations.
POLYG	<u>Polygonum</u> (Polyg.)	Th	Native and alien spp., mainly along stream banks, lower elevations.
CENT 1	Centrospermae p.p., D<20μ	Ch,Th	Mainly Chenopodiaceae and Amaranthaceae: may include some Caryophyllaceae. Shrubs and herbs, particularly of low rainfall areas of tableland and western plains.
CENT 2	" D>20μ		
CENT 3	Centrospermae, type 74	?	Possibly Caryophyllaceae.
GYROS	Gyrostemonaceae	M,N	<u>Gyrostemon</u> and <u>Codonocarpus</u> : Shrubs of semi-arid areas of inland Australia.
NEOPX	<u>Neopaxia australasica</u> (Portulacaceae)	Ch	Mat-forming stoloniferous herb, typically of disturbed sites. Higher elevations.
STELL	<u>Stellaria</u> (Caryophyllaceae)	H	Common herbs of forest areas. Also introduced spp., disturbed areas.
RANUN	Ranunculaceae	H,G,HH M, N	<u>Ranunculus</u> spp. & <u>Caltha introloba</u> . Mainly higher elevations, damp sites. <u>Clematis</u> spp. vines of moist forest.
ATHER	<u>Atherosperma</u> (Monimiaceae)	MM	Restricted to small pure stands steep SE aspects, 800-1,300 m, in mountain gullies.
CRUCI	Cruciferae	H,Th	Steep moist sites at higher elevations. Naturalised aliens in disturbed sites.
BURSA	<u>Bursaria spinosa</u> (Pittosporaceae)	N	Along gullies, forested areas.
ACAEN	<u>Acaena</u> (Rosaceae)	Ch,H	Colonising herbs, all elevations.
ACACI	<u>Acacia</u> (Mimosaceae)	MM,M,N	<u>A. alpina</u> only sp. which extends above forest limit - rest mainly woodland and forests, esp. after fire.
HARDE	<u>Hardenbergia</u> sim. (Papilionaceae)	N,Ch	Vines and shrubs of dry sclerophyll forests to 1,000m.
BOSSI	<u>Bossiaea</u> sim. (Pap.)	N,Ch	Includes <u>Mirbelia</u> and <u>Platylobium</u> : common shrubs of forests.
TRIFO	<u>Trifolium</u> sim. (Pap.)	H,Th	Includes several introduced genera, mainly in pastures and disturbed areas.
DAVIE	<u>Daviesia</u> sim. (Pap.)	M,N	Includes <u>Oxylobium</u> , <u>Pultenaea</u> . Very common shrubs of dry sclerophyll forests and subalpine heaths (<u>Oxylobium</u>).
HOVEA	<u>Hovea</u> sim. (Pap.)	N,Ch	Includes spp. at all elevations: forests and alpine heaths.

Table D.1 Pollen taxa information.

CODE	POLLEN TAXON	LIFE FORM	KNOWN ECOLOGY AND DISTRIBUTION
PHEBA	<u>Phebalium</u> comp. (Rutaceae)	N,Ch	Shrub communities of higher elevations.
CORRE	<u>Correa lawrenciana</u> (Rut.)	N	Shrub of wet sclerophyll forests, to 1,700 m.
ERIOS	<u>Eriostemon</u> sim. (Rut.)	N	Includes <u>Boronia</u> : heath and forests.
TETRA	<u>Tetralochea</u> (Tremandraceae)	N,Ch	Heath and forests below 1,200 m.
PGALA	Polygalaceae	Ch	Shrubs, herbs of variety of situations to subalpine levels but rarely common.
DODON	<u>Dodonaea</u> (Sapindaceae)	M,N,Ch	Dry forests and woodland of lower elevations.
POMAD	<u>Pomaderris</u> (Rhamnaceae)	M,N	Sclerophyll forests below 1,400 m.
HIBBE	<u>Hibbertia</u> comp. (Dilleniaceae)	N,Ch	Forests below 1,500 m.
HYPER	<u>Hypericum</u> comp. (Hypericaceae)	H,Th	Native and alien spp., below 1,500 m, mainly forested areas.
DRIMY	<u>Drimys</u> (Winteraceae)	N,Ch	Forests and Shrub communities at high elevations, esp. in cool moist gullies.
PIMEL	<u>Pimelea</u> sim. (Thymelaeaceae)	N,Ch	Common at all elevations; forests and heaths.
KUNZE	<u>Kunzea</u> comp. (Myrtaceae)	N,Ch	Alpine and lowland heaths.
CALLI	<u>Callistemon</u> comp. (Myrt.)	N	Swamps and watercourses to subalpine levels.
EUCAL	<u>Eucalyptus</u> (Myrt.)	MM,M	Dominant forest tree and as krummholtz to 2,000 m.
ANGOP	<u>Angophora</u> (Myrt.)	MM	Subdominant forest tree, coastal areas.
LEPTO	<u>Leptospermum</u> sim. (Myrt.)	M,N	Includes <u>Baekkaea</u> : Shrubs of watercourses, all elevations.
EPILO	<u>Epilobium</u> (Onagraceae)	Ch	Swampy sites, esp. at higher elevations.
HALOR	Haloragaceae	Ch,HH	<u>Haloragis</u> spp.: herbs esp. of swampy sites in woodland or grassland: <u>Myriophyllum</u> aquatic.
MYRIO	<u>Myriophyllum pedunculatum</u> (Halorag.)	HH	Common in swamps at high elevations.
TIEGH	<u>Tieghemopanax sambucifolius</u> (Araliaceae)	N	Wet sclerophyll forests, common 1,000-1,400m.
HYDRO	<u>Hydrocotyle</u> sim. (Apiaceae)	H	Grasslands and forests, damp sites, all elevations.
ACIPH	<u>Aciphylla</u> sim. (Ap.)	H	Alpine herbfield (includes <u>Oreomyrrhis</u> , <u>Diplaspis</u>), damp sites.
DICHO	<u>Dichosciadium ranunculaceum</u> (Ap.)	H	Gravelly watercourses above 1,900m, esp. <u>Caltha</u> .
SCHIZ	<u>Schizeilema fragoseum</u> (Ap.)	Ch	Fern-bed communities among boulders, above 1,800m.
EPACR	Epacridaceae	N,Ch	Forests and swamp heaths, all elevations.
EPSE	<u>Epacris serpyllifolia</u> (Epac.)	Ch	Alpine wet heaths.
MONOT	<u>Monotoca</u> comp. (Epac.)	N,Ch	Includes some <u>Leucopogon</u> spp. : forests and swampy sites: not alpine.
CENTA	<u>Centaurium</u> (Gentianaceae)	Th	Naturalised aliens: disturbed sites in forests.
GENTI	<u>Gentianella diemensis</u> (Gent.)	Ch	Grassland and herbfield of higher elevations.
BORAG	Boraginaceae	H,Th	Naturalised aliens mainly, disturbed areas: native species in woodland.
ECHIU	<u>Echium lycopsis</u> (Borag.)	H	"Paterson's Curse" - weed of pastures and crops : not in mountains.
PROST	<u>Prostanthera</u> (Lamiaceae)	M,N,Ch	Shrubs of alpine heaths and wet sclerophyll forests.
EUPHR	<u>Euphrasia</u> (Scrophulariaceae)	Ch,Th	Typically in alpine herbfield, also forests above 1000m.
PARAH	<u>Parahebe</u> comp. (Scroph.)	G	Wet sclerophyll forests esp. at higher elevations: increased by disturbance.
GRATI	<u>Gratiola</u> comp. (Scroph.)	HH	Swampy areas to 1,700 m.
UTRIC	<u>Utricularia</u> (Lentibulariaceae)	HH	Swamp plants, all elevations.
MYOPO	Myoporaceae	M,N,Ch	<u>Myoporum</u> and <u>Eremophila</u> : shrubs of drier lowland areas.
PLANL	<u>Plantago lanceolata</u> sim. (Plantaginaceae)	H	Naturalised aliens, disturbed areas except alpine.
PLANM	<u>Plantago muelleri</u> sim.	H	Native spp., wetter sites in alpine herbfield also less importantly, at lower elevations.
COPRO	<u>Coprosma</u> (Rubiaceae)	N,Ch	Shrubs of wet sclerophyll forest and feldmark
ASPER	<u>Asperula</u> comp. (Rub.)	G	Common at all elevations on drier sites.
WAHLE	<u>Wahlenbergia</u> (Campanulaceae)	Ch,Th	Sclerophyll forest, grassland and herbfield, all elevations.
STYLI	<u>Stylidium</u> (Stylidiaceae)	Ch	Common at all elevations, wide variety of sites.

Table D.1 (continued)

CODE	POLLEN TAXON	LIFE FORM	KNOWN ECOLOGY AND DISTRIBUTION
TUB 1	Asteraceae subf. Tubuliflorae D<15 μ	} M,N,Ch, H,G,Th	Important components of all communities except those of swampy sites.
TUB 2	15-20 μ		
TUB 3	20-25 μ		
TUB 4	25-30 μ		
TUB 5	D>30 μ		
LIGUL	Asteraceae subf. Liguliflorae	H,Th	<u>Microseris</u> native, but mainly naturalised aliens: disturbed sites at all elevations.
EWART	<u>Ewartia</u> sim. (Ast.)	Ch	Mat-forming herb colonising bare patches, drier sites in alpine herbfield, grassland and feldmark.
PODOC	<u>Podocarpus</u> comp. (Podocarpaceae)	MM,M,N-Ch	<u>P. lawrencei</u> among boulders at high elevations rainforest trees, eastern Australia.
DACRY	<u>Dacrydium</u> comp. (Pod.)	MM	Cool rainforest tree, Tasmania, New Zealand, New Guinea.
CUPRE	<u>Callitris</u> (Cupressaceae)	MM,M	Dry sclerophyll forest and woodland, lower elevations: 38 - 64cm rainfall.
PINUS	<u>Pinus radiata</u> (Pinaceae)	MM	Introduced tree extensively planted in previous wet sclerophyll forest areas, below 1200m: not yet naturalised.
LYCSE	<u>Lycopodium selago</u> (Lycopodiaceae)	H	Sphagnum bogs above 1,500 m, uncommon.
LYCFA	<u>Lycopodium fastigiatum</u>	H	Shaded places above 1,500 m; more common than <u>L. selago</u> .
OPHIO	<u>Ophioglossum</u> (Ophioglossaceae)	H	Swampy woodland at lower elevations.
FILIM	Filicinae, monolete		Mainly <u>Blechnum</u> (H-HH, all elevations), also other fern spores with eroded perine.
FILIT	Filicinae, trilete		Includes <u>Adiantum</u> , <u>Pteridium</u> and possibly other genera, none above 1,500 m.
F 137	Filicinae type 137	-	Possibly Davalliaceae: Probably wet sclerophyll forest.
F156	Filicinae type 156	-	Probably wet sclerophyll forest.
PELLE	<u>Pellaea falcata</u> (Adiantaceae)	H	Rocky places, woodland and dry sclerophyll forest, below 1,500 m.
CHEIL	<u>Cheilanthes</u> (Adiant.)	H	Similar to <u>Pellaea</u> .
DICKS	<u>Dicksonia antarctica</u> (Dicksoniaceae)	N	Tree ferns, shaded slopes or near water, wet sclerophyll forest, below 1,350 m.
HYPOL	<u>Hypolepis</u> (Dennstaedtiaceae)	H	Shaded forest gullies below 1,500m.
CULCI	<u>Culcita dubia</u> (Denn.)	H	Common in forest clearings, lower elevations.
ASPLE	<u>Asplenium</u> (Aspleniaceae)	H,E	Common in rocky crevices and on tree trunks, wetter sites, all elevations.
POLYS	<u>Polystichum proliferum</u> (Aspidiaceae)	H	Very common in wet sclerophyll forest and shaded alpine sites.
GRAMM	<u>Grammitis</u> (Grammitidaceae)	H,E	Wet sclerophyll forests 900-1,700m.
UNIDE	Unidentifiable pollen and spores	-	
UNKNO	Unknown pollen and spores	-	
SPH W	'Sphere-W'	Plankton	Present in Blue Lake. Unknown ecology and distribution.
SPH R	'Sphere-R'	"	" " " " " " " "
SPH F	'Sphere-F'	"	" " " " " " " "
SPH P	'Sphere-P'	"	Possibly <u>Trochiscia</u> sp., an alga.
ACRIT	<u>Baltisphaeridium</u> sp.	"	B. spp: reported from Western Australia, S.E. Australia; freshwater.
BOTRY	<u>Botryococcus braunii</u>	"	Widespread freshwater alga.
TSUGA	<u>Tsuga canadensis</u>	-	Exotic pollen used as tracer in some preparations. Rarely planted as garden tree in Australia.

Table D.1 (continued).

Table D.2

Blue Lake Core 1

Slide Code	Sample Depth (cm)	Pollen Count	Sample Fraction Counted	Pollen Concentration (grains/cc)	Pollen Deposition Rate (grains/cm ² /yr) est. \pm std. error
BL1 437 1	20	157	0.00040	416050	27100 \pm 2300
BL1 417 1	39	185	"	490250	31900 \pm 2500
BL1 397 1	59	157	"	416050	27100 \pm 2300
BL1 377 1	78	178	"	471700	30700 \pm 2500
BL1 357 1	97	110	"	323300	21000 \pm 1500
BL1 357 2	97	134	"		
BL1 337 1	116	149	"	392200	25500 \pm 1700
BL1 337 2	116	147	"		
BL1 317 1	135	185	"	496870	32300 \pm 1900
BL1 317 2	135	190	"		
BL1 297 1	154	146	"	351570	22900 \pm 1300
BL1 297 2	154	252	0.00080		
BL1 277 1	173	177	0.00040	469050	30500 \pm 2500
BL1 257 1	192	162	"	429300	27900 \pm 2300
BL1 237 1	211	114	"	327270	21000 \pm 1500
BL1 237 2	211	133	"		
BL1 217 1	230	167	"	559030	35200 \pm 2900
BL1 197 1	249	174	"	461100	27800 \pm 2300
BL1 177 1	268	185	"	490250	27300 \pm 2200
BL1 157 1	287	170	"	450500	23800 \pm 2000
BL1 137 1	306	123	"	331250	16900 \pm 1200
BL1 137 2	306	127	"		
BL1 117 1	325	157	"	416050	20400 \pm 1700
BL1 97 1	344	126	"	348470	17100 \pm 1200
BL1 97 2	344	137	"		
BL1 77 1	363	198	"	524700	26200 \pm 2000
BL1 57 1	382	254	"	673100	36200 \pm 2500
BL1 37 1	402	165	"	437250	26400 \pm 2200
BL1 17 1	421	157	"	393790	27500 \pm 1800
BL1 17 2	421	140	"		

TABLE D.2.1

	TYPHA	TRIGL	POA 1	POA 2	POA 3	POA 4	POA 5	POA 6	POA A	CYPER	RESTI	XYRIS	ASPHO	DIANE	ASTEL		
BL1	437	1	0	0	0	8	18	12	3	0	3	8	4	0	0	0	1
BL1	417	1	2	0	0	8	20	15	3	0	12	16	0	0	0	0	3
BL1	397	1	0	0	0	7	19	10	1	0	7	7	5	0	0	0	2
BL1	377	1	2	0	0	15	17	15	2	0	17	3	0	0	0	0	1
BL1	357	1	0	0	1	2	11	7	0	0	2	4	1	0	0	0	0
BL1	357	2	0	0	0	13	22	7	3	0	6	0	0	0	0	0	1
BL1	337	1	0	0	0	6	13	11	7	0	27	3	0	0	0	0	0
BL1	337	2	0	0	0	5	8	15	5	0	18	6	1	0	0	0	0
BL1	317	1	2	0	0	8	8	13	9	0	29	3	0	0	0	0	0
BL1	317	2	1	0	0	0	10	22	17	1	0	27	8	0	0	0	1
BL1	297	1	1	0	0	9	13	9	2	0	11	4	1	0	0	0	0
BL1	297	2	1	0	0	15	11	23	0	0	26	5	0	0	0	0	2
BL1	277	1	0	0	6	25	19	6	3	0	5	4	1	0	0	0	0
BL1	257	1	1	0	0	18	16	12	4	0	16	4	0	0	2	0	1
BL1	237	1	0	0	0	5	16	2	3	0	5	6	1	0	0	0	2
BL1	237	2	0	0	1	8	17	8	2	0	0	5	2	0	0	0	1
BL1	217	1	0	0	7	18	13	5	2	0	7	7	1	0	1	0	0
BL1	197	1	1	0	0	11	10	13	11	0	15	6	0	0	0	0	3
BL1	177	1	0	0	0	6	14	7	4	0	14	13	8	0	0	1	0
BL1	157	1	0	0	0	9	15	16	3	0	16	3	0	0	0	0	1
BL1	137	1	0	0	1	7	9	3	2	0	5	5	0	0	0	0	1
BL1	137	2	0	0	1	6	14	10	3	0	0	2	0	0	0	0	2
BL1	117	1	0	0	0	5	11	11	3	0	9	7	0	0	0	0	4
BL1	97	1	0	0	0	12	12	7	0	0	11	4	0	0	0	0	1
BL1	97	2	0	0	0	8	13	6	4	0	0	3	0	0	1	0	1
BL1	77	1	0	0	0	13	17	9	4	0	12	8	1	0	0	0	1
BL1	57	1	0	0	8	27	23	10	1	0	6	8	0	0	0	0	8
BL1	37	1	0	0	0	5	10	5	2	0	13	12	0	0	0	0	6
BL1	17	1	0	0	0	5	9	8	0	0	14	8	3	0	0	0	0
BL1	17	2	0	0	0	2	9	6	3	0	0	5	1	0	0	0	3

TABLE D.2.2

CASUA URTIC GREVI HAKEA BANKS LOMAT EXOCA AMYEM RUMEX POLYG CENT1 CENT2 CENT3 GYROS NEOPX

BL1	437	1	5	0	0	0	0	0	0	0	0	0	0	5	2	0	0	0
BL1	417	1	6	0	0	0	0	0	0	0	0	0	0	2	4	1	0	0
BL1	397	1	2	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0
BL1	377	1	1	0	0	0	0	0	0	0	0	0	0	5	2	0	0	0
BL1	357	1	2	0	0	0	0	0	0	0	0	0	0	4	7	0	0	0
BL1	357	2	2	0	0	0	0	0	0	0	0	0	0	2	3	0	0	0
BL1	337	1	1	0	0	0	0	0	0	0	0	0	0	5	5	0	0	0
BL1	337	2	4	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0
BL1	317	1	7	0	0	0	0	0	0	0	0	0	0	4	4	0	0	0
BL1	317	2	7	0	0	0	0	0	0	0	0	0	0	4	4	0	0	0
BL1	297	1	4	1	0	0	0	0	0	0	0	0	0	3	2	0	0	0
BL1	297	2	6	0	0	0	0	2	0	0	0	0	0	4	7	0	0	0
BL1	277	1	4	0	0	0	0	0	0	0	0	0	0	1	3	0	0	0
BL1	257	1	2	0	0	0	0	0	0	0	0	0	0	3	4	0	0	0
BL1	237	1	5	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0
BL1	237	2	5	0	0	0	0	0	0	0	0	0	0	2	4	1	0	0
BL1	217	1	6	1	0	0	0	1	0	0	0	0	0	8	2	0	0	0
BL1	197	1	6	0	0	0	0	0	0	0	0	0	0	4	1	1	0	0
BL1	177	1	3	0	0	0	0	0	0	0	0	0	0	4	1	1	0	0
BL1	157	1	0	0	0	0	0	0	0	0	0	0	0	2	8	1	0	0
BL1	137	1	4	0	0	0	0	0	0	0	0	0	0	1	2	2	0	0
BL1	137	2	2	1	0	0	0	0	0	0	0	0	0	3	2	0	0	0
BL1	117	1	7	0	0	0	0	0	0	0	0	0	0	1	3	0	0	0
BL1	97	1	2	0	0	0	0	0	0	0	0	0	0	1	4	1	0	0
BL1	97	2	2	0	0	0	0	0	0	0	0	0	0	4	2	0	0	0
BL1	77	1	6	0	0	0	0	0	0	0	0	0	0	3	7	0	0	0
BL1	57	1	8	7	0	0	0	0	0	0	0	0	0	6	3	0	1	0
BL1	37	1	4	0	0	0	0	0	0	0	0	0	0	3	3	1	0	1
BL1	17	1	1	0	0	0	0	0	0	0	0	0	0	3	4	0	0	0
BL1	17	2	7	0	0	0	0	0	0	0	0	0	0	4	0	0	1	0

TABLE D.2.3

STELL BANUN ATHER CRUCI BURSA ACAEN ACACI HARDE BOSSI TRIFO DAVIE HOVEA PHEBA CORRE ERIOS

BL1	437	1	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0
BL1	417	1	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0
BL1	397	1	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0
BL1	377	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
BL1	357	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
BL1	357	2	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
BL1	337	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
BL1	337	2	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
BL1	317	1	0	1	0	0	1	0	0	0	0	0	1	0	0	0	1
BL1	317	2	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
BL1	297	1	0	0	0	0	1	1	0	0	0	0	0	0	0	0	1
BL1	297	2	0	3	0	0	0	0	1	0	0	0	0	1	0	0	1
BL1	277	1	0	1	0	0	1	0	0	0	0	0	0	0	0	0	1
BL1	257	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BL1	237	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
BL1	237	2	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
BL1	217	1	0	1	0	0	0	1	0	0	0	0	0	1	0	0	0
BL1	197	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BL1	177	1	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0
BL1	157	1	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0
BL1	137	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
BL1	137	2	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0
BL1	117	1	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0
BL1	97	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
BL1	97	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BL1	77	1	0	1	0	0	1	0	0	0	0	0	0	0	0	0	1
BL1	57	1	0	2	0	0	0	0	1	0	0	0	0	0	0	0	1
BL1	37	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
BL1	17	1	0	2	0	0	0	0	0	1	0	0	0	0	0	0	1
BL1	17	2	0	2	0	0	0	0	1	1	0	0	0	0	0	0	1

TABLE D.2.4

TETRA BGALA DODON POMAD HIBBE HYPER DRIMY PIMEL KUNZE CALLI EUCAL ANGOP LEPTO EPILO HALOR

BL1	437	1	0	0	2	3	0	0	0	0	1	0	44	0	1	0	1
BL1	417	1	00	00	3	2	00	00	00	00	0	00	38	00	1	00	0
BL1	397	1	00	00	1	1	00	00	00	00	2	00	35	00	4	00	0
BL1	377	1	00	00	0	2	00	00	00	00	0	00	42	00	0	00	2
BL1	357	1	00	00	1	0	00	00	00	00	1	00	33	00	4	00	0
BL1	357	2	00	00	0	0	00	00	00	00	0	00	41	1	2	00	1
BL1	337	1	00	00	0	0	00	00	00	00	1	00	34	00	1	00	2
BL1	337	2	00	00	0	0	00	00	00	00	0	00	35	00	1	00	2
BL1	317	1	00	00	0	0	00	00	1	00	1	00	43	00	3	00	1
BL1	317	2	00	00	0	0	00	00	1	00	0	00	37	00	4	00	3
BL1	297	1	00	00	1	2	00	00	00	00	1	00	35	00	4	00	1
BL1	297	2	00	00	0	2	00	00	00	00	1	00	63	00	1	00	2
BL1	277	1	00	00	0	0	00	00	1	00	1	00	38	00	5	00	0
BL1	257	1	00	00	0	0	00	00	00	00	0	00	38	00	1	1	2
BL1	237	1	00	00	2	4	00	00	00	00	0	00	28	00	2	00	2
BL1	237	2	00	00	0	4	00	00	00	00	0	00	27	00	1	00	2
BL1	217	1	00	00	1	0	00	00	00	1	00	00	37	00	6	00	0
BL1	197	1	00	00	0	2	00	00	00	00	0	00	43	00	3	00	0
BL1	177	1	00	00	0	1	00	00	00	00	0	00	35	00	3	00	3
BL1	157	1	00	00	0	2	00	00	1	00	0	00	37	00	2	00	1
BL1	137	1	00	00	1	2	00	00	1	00	0	00	29	00	1	00	2
BL1	137	2	00	00	0	2	00	00	0	00	0	00	29	00	2	00	0
BL1	117	1	00	00	0	6	00	00	00	00	0	00	40	00	4	00	2
BL1	97	1	00	00	0	4	00	00	00	00	0	00	35	00	3	00	0
BL1	97	2	00	00	0	7	00	00	1	00	0	00	32	00	3	00	1
BL1	77	1	00	00	1	8	00	00	0	00	2	00	44	00	2	00	0
BL1	57	1	00	00	1	9	00	00	1	00	0	00	40	00	9	00	8
BL1	37	1	00	00	3	16	00	00	0	00	1	00	40	00	5	00	1
BL1	17	1	0	0	3	15	00	00	0	00	0	00	36	00	6	00	1
BL1	17	2	1	0	1	24	00	00	0	00	0	00	18	00	1	00	0

TABLE D.2.6

PARAH RATI UTRIC MYOPO PLANL PLANM COPRO ASPER WAHLE STYLI TUB 1 TUB 2 TUB 3 TUB 4 TUB 5

BL1	437	1	0	0	0	0	0	0	0	0	0	0	0	6	4	3	1
BL1	417	1	0	0	0	0	0	1	0	0	0	0	0	5	5	3	1
BL1	397	1	0	0	0	0	1	0	0	0	0	0	0	8	4	2	3
BL1	377	1	0	0	0	0	0	0	0	0	0	0	0	6	2	4	2
BL1	357	1	0	0	0	0	0	0	0	0	0	0	0	3	2	5	0
BL1	357	2	0	0	0	0	0	0	0	0	0	0	0	3	4	3	0
BL1	337	1	0	0	0	0	0	0	0	0	0	1	0	3	1	2	2
BL1	337	2	0	0	0	0	0	0	0	0	0	0	0	5	2	2	2
BL1	317	1	0	0	0	0	0	0	0	0	0	0	0	3	3	6	2
BL1	317	2	0	0	0	0	0	1	0	0	0	0	0	5	6	3	0
BL1	297	1	0	0	0	0	0	2	0	0	0	0	0	8	6	2	1
BL1	297	2	0	0	0	0	0	1	0	0	0	0	0	5	7	6	5
BL1	277	1	0	0	0	0	0	4	0	0	0	0	0	7	5	2	0
BL1	257	1	0	0	0	0	0	0	0	0	0	0	0	4	2	2	1
BL1	237	1	0	0	0	0	0	0	0	0	0	0	0	1	5	3	0
BL1	237	2	1	0	0	0	0	0	0	0	0	0	0	4	4	2	0
BL1	217	1	0	0	0	1	0	3	0	0	0	0	0	8	3	2	1
BL1	197	1	0	0	0	0	0	1	0	0	0	0	1	2	4	2	3
BL1	177	1	0	0	0	0	0	2	0	0	0	0	0	4	4	5	0
BL1	157	1	0	0	0	0	0	0	0	0	0	0	0	4	7	5	4
BL1	137	1	0	0	0	0	0	0	0	1	0	0	0	5	5	5	1
BL1	137	2	0	0	0	0	0	2	0	0	0	0	0	5	4	3	0
BL1	117	1	0	0	0	0	0	0	0	0	1	0	0	3	3	5	1
BL1	97	1	0	0	0	0	0	0	0	0	0	0	0	1	5	2	0
BL1	97	2	1	0	0	0	0	1	0	0	0	0	0	2	3	1	2
BL1	77	1	0	0	0	0	0	0	0	0	0	0	0	2	4	3	2
BL1	57	1	1	0	0	0	0	2	0	0	0	0	6	6	4	0	0
BL1	37	1	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0
BL1	17	1	0	0	0	0	0	1	0	0	0	0	0	0	5	1	3
BL1	17	2	1	0	0	1	0	1	1	0	0	0	0	1	4	0	0

TABLE D.2.7

LIGUL EWART PODOC DACRY CUPRE PINUS LYCSE LYCFA OPHIO FILIM FILIT F 137 F 156 PELLE CHEIL.

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BL1	437	1	0	0	1	0	0	0	0	1	0	5	1	0	0	0	0
BL1	417	1	0	0	0	0	0	3	0	0	0	8	3	0	0	0	0
BL1	397	1	0	0	1	0	0	1	1	0	0	8	2	1	0	0	0
BL1	377	1	0	0	1	0	0	1	1	1	0	7	2	0	0	0	0
BL1	357	1	0	0	0	0	0	0	0	0	0	3	4	0	0	0	0
BL1	357	2	0	0	1	0	0	1	2	0	0	1	0	0	0	0	0
BL1	337	1	0	0	0	0	0	1	0	0	0	8	2	0	0	0	0
BL1	337	2	0	0	0	0	0	0	0	0	0	9	1	0	0	0	0
BL1	317	1	0	0	0	0	0	0	0	0	0	5	5	0	0	0	0
BL1	317	2	0	0	0	0	0	1	0	0	0	7	0	0	0	0	0
BL1	297	1	0	0	1	0	0	0	0	0	0	5	5	0	0	0	0
BL1	297	2	0	0	1	0	0	6	0	0	0	7	3	0	1	0	1
BL1	277	1	0	0	0	0	0	0	0	0	0	4	5	0	0	0	0
BL1	257	1	0	0	1	0	0	0	0	1	0	4	5	0	0	0	0
BL1	237	1	0	0	1	0	0	0	0	0	0	8	1	0	0	1	0
BL1	237	2	0	0	0	0	0	1	0	0	0	3	4	0	0	0	0
BL1	217	1	0	0	3	0	0	0	0	0	0	5	3	0	0	0	0
BL1	197	1	0	0	2	0	0	2	0	0	0	6	5	0	0	0	0
BL1	177	1	0	0	1	0	0	1	0	0	0	6	6	0	0	0	0
BL1	157	1	0	0	1	0	0	0	0	0	0	6	6	0	0	0	0
BL1	137	1	0	0	0	0	0	0	0	0	0	9	6	0	0	0	0
BL1	137	2	0	0	2	0	0	0	1	0	0	8	9	0	0	0	1
BL1	117	1	0	0	4	0	0	0	0	0	0	4	2	0	0	0	1
BL1	97	1	0	0	1	0	0	1	0	0	0	4	2	0	0	0	0
BL1	97	2	0	0	1	0	0	1	0	0	0	6	5	0	0	0	0
BL1	77	1	0	0	1	0	0	1	0	0	0	4	3	0	0	0	0
BL1	57	1	0	0	1	0	0	0	0	1	0	4	1	0	0	0	0
BL1	37	1	0	0	1	0	0	0	0	0	0	8	3	0	0	0	1
BL1	17	1	0	0	1	0	0	0	0	0	0	8	1	0	0	0	0
BL1	17	2	0	0	1	0	0	0	0	0	0	9	4	0	0	0	0

TABLE D.2.8

DICKS WYPOL CULCI ASPLE POLYS GRAMM UNIDE UNKND SPH W. SPH R SPH F SPH P ACRIT BOTRY TSUGA

BL1	437	1	0	0	0	0	0	0	3	0	87	2	0	2	0	2	37
BL1	417	1	0	0	0	0	0	0	12	0	116	0	0	0	0	4	52
BL1	397	1	0	0	0	0	0	0	3	2	150	6	1	0	0	3	58
BL1	377	1	0	0	0	0	0	0	10	3	95	0	0	0	0	4	3
BL1	357	1	1	0	0	0	0	0	4	0	51	1	0	0	0	3	33
BL1	357	2	0	0	0	0	0	0	8	0	59	1	0	0	0	1	2
BL1	337	1	0	0	0	0	0	0	5	1	47	0	0	0	0	1	0
BL1	337	2	0	0	0	0	0	0	8	0	53	0	0	0	0	2	0
BL1	317	1	0	0	0	0	0	0	10	0	110	1	0	0	0	3	0
BL1	317	2	0	0	0	0	0	0	5	2	114	0	0	0	0	3	0
BL1	297	1	0	0	0	0	0	0	5	1	62	0	0	0	0	0	0
BL1	297	2	0	0	0	0	0	0	14	2	94	0	0	0	0	1	3
BL1	277	1	1	0	0	0	0	0	5	0	139	5	0	0	1	2	16
BL1	257	1	0	0	0	0	0	0	8	1	81	2	0	0	0	0	44
BL1	237	1	1	0	0	0	0	0	4	1	76	1	0	0	2	2	53
BL1	237	2	0	0	0	0	0	0	11	2	92	12	0	0	1	6	61
BL1	217	1	0	0	0	0	0	0	4	1	100	1	0	0	1	2	25
BL1	197	1	1	0	0	0	0	0	6	1	77	7	0	0	3	0	60
BL1	177	1	1	0	0	0	0	0	7	0	85	1	0	0	1	0	71
BL1	157	1	0	1	0	0	0	0	6	0	55	4	0	0	15	3	73
BL1	137	1	0	0	0	0	0	0	5	1	53	1	0	0	11	1	60
BL1	137	2	1	0	0	0	0	0	4	1	28	2	0	0	10	3	63
BL1	117	1	0	0	0	0	0	0	5	0	36	2	0	0	6	2	81
BL1	97	1	1	0	0	0	0	0	2	0	28	2	0	0	2	0	82
BL1	97	2	2	0	1	0	0	0	7	2	28	1	0	0	4	2	55
BL1	77	1	2	0	0	0	0	0	7	3	32	1	0	0	1	4	56
BL1	57	1	1	0	1	0	0	0	4	2	53	4	0	0	13	1	52
BL1	37	1	4	0	1	0	0	0	6	2	17	1	0	0	23	4	48
BL1	17	1	0	0	0	0	0	1	13	1	12	0	0	0	10	1	56
BL1	17	2	1	4	0	0	1	0	12	1	15	0	0	0	6	5	58

TABLE D.3

Blue Lake Core 3

Slide Code	Sample Depth (cm)	Pollen Count	Sample Fraction Counted	Pollen Concentration (grains/cc)	Pollen Deposition Rate (grains/cm ² /yr) est. ± std. error
BL3 0 1	260	176	0.00040	466400	26800 ± 2200
BL3 20 1	280	208	"	551200	29600 ± 2200
BL3 40 1	300	146	"	386900	19700 ± 1700
BL3 60 1	320	169	"	447850	22400 ± 1800
BL3 80 1	340	158	"	418700	20500 ± 1700
BL3 100 1	360	180	"	477000	23800 ± 1900
BL3 118 1	378	222	"	588300	31100 ± 2300
BL3 140 1	400	170	"	450500	27200 ± 2200
BL3 160 1	420	195	"	516750	36100 ± 2800
BL3 180 1	440	184	"	487600	38200 ± 3000
BL3 200 1	460	203	"	537950	44700 ± 3400
BL3 220 1	480	243	"	643950	54700 ± 3900
BL3 240 1	500	214	"	567100	41200 ± 3100
BL3 260 1	520	304	"	805600	37200 ± 2400
BL3 280 1	540	252	"	667800	11970 ± 830
BL3 300 1	560	181	"	451030	9790 ± 780
BL3 320 1	580	107	"	314470	9200 ± 560
BL3 320 2	580	249	0.00080		
BL3 340 1	600	67	0.00040	158120	5970 ± 480
BL3 340 2	600	112	0.00080		
BL3 360 1	620	141	0.00040	361720	17100 ± 1150
BL3 360 2	620	132	"		
BL3 380 1	640	112	"	251750	13300 ± 1070
BL3 380 2	640	78	"		
BL3 400 1	660	27	"	91160	5500 ± 450
BL3 400 2	660	58	0.00080		
BL3 400 3	660	87	"		

TABLE D.3.1

	TYPHA	TRIGI	POA 1	POA 2	POA 3	POA 4	POA 5	POA 6	POA A	CYPER	RESTI	XYRIS	ASPHO	DIANE	ASTEL
BL3	0	1	0	20	13	5	2	0	6	5	3	0	0	0	5
BL3	20	1	0	15	20	14	10	0	6	13	0	0	0	0	6
BL3	40	1	0	6	19	12	3	0	9	9	1	0	1	0	5
BL3	60	1	1	11	16	11	6	0	8	4	2	0	0	0	3
BL3	80	1	0	15	14	7	3	0	9	5	0	0	0	0	1
BL3	100	1	0	3	24	8	6	0	6	5	1	0	0	2	7
BL3	118	1	0	21	23	17	5	0	1	15	5	0	0	0	4
BL3	140	1	0	11	24	7	4	0	3	6	4	0	0	0	5
BL3	160	1	0	15	15	10	2	0	3	13	0	0	1	0	7
BL3	180	1	0	16	19	12	2	0	5	7	2	0	0	0	3
BL3	200	1	1	10	10	7	6	0	4	15	0	0	0	0	5
BL3	220	1	2	18	22	9	3	0	10	16	0	0	0	0	4
BL3	240	1	0	17	27	14	6	0	6	7	1	0	0	0	6
BL3	260	1	1	2	27	16	4	0	13	10	0	0	0	0	3
BL3	280	1	0	5	25	28	1	0	10	12	1	0	0	0	0
BL3	300	1	0	9	23	16	5	0	4	4	1	1	0	0	1
BL3	320	2	2	8	18	9	2	0	3	3	0	0	0	0	0
BL3	340	1	1	1	24	25	7	0	0	2	0	0	0	0	0
BL3	360	2	0	0	6	3	1	0	2	1	1	0	0	0	0
BL3	380	1	0	7	14	14	1	0	0	2	0	0	0	0	0
BL3	400	2	0	0	16	7	3	0	2	4	1	0	0	0	0
BL3	420	1	0	15	16	6	1	0	0	2	0	0	0	0	0
BL3	440	2	1	12	10	7	2	0	3	1	0	0	0	0	0
BL3	460	2	2	15	11	2	1	0	0	0	0	0	0	0	0
BL3	480	1	0	4	5	0	0	0	0	0	0	0	0	0	0
BL3	500	2	0	1	6	1	0	0	5	0	0	0	0	0	0
BL3	520	3	0	3	13	2	1	0	6	0	0	0	0	0	0

TABLE D.3.2

CASUA URTIC GREVI HAKEA BANKS LOMAT EXOCA AMYEM RUMEX POLYG CENT1 CENT2 CENT3 GYROS NEOPX

BL3	0	1	4	0	0	0	0	0	0	0	0	0	0	5	2	0	0	0
BL3	200	1	8	0	0	0	0	0	0	0	0	0	0	5	5	0	0	0
BL3	400	1	5	0	0	0	0	0	0	0	0	0	0	2	3	0	0	0
BL3	600	1	3	0	0	0	0	0	0	0	0	0	0	2	2	0	0	0
BL3	800	1	1	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0
BL3	1000	1	4	0	0	0	0	0	0	0	0	0	0	3	4	1	0	0
BL3	1180	1	9	0	0	0	0	0	0	0	0	0	0	4	4	1	0	0
BL3	1400	1	3	0	0	0	0	0	0	0	0	0	0	2	4	2	0	0
BL3	1600	1	8	0	0	0	0	0	0	0	0	0	0	4	2	0	0	0
BL3	1800	1	6	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0
BL3	2000	1	5	0	0	0	0	0	0	0	0	0	0	3	2	1	0	0
BL3	2200	1	8	0	0	0	0	0	0	0	0	0	0	1	4	2	0	0
BL3	2400	1	8	1	0	0	0	0	0	0	0	0	0	1	2	2	0	0
BL3	2600	1	11	1	0	0	0	0	0	0	0	0	0	11	6	1	0	0
BL3	2800	1	9	0	0	0	0	0	0	0	0	0	0	17	3	0	1	0
BL3	3000	1	6	0	0	0	0	0	0	0	0	0	0	19	5	1	0	0
BL3	3200	2	12	0	0	0	0	0	0	0	0	0	0	4	3	0	1	0
BL3	3400	1	4	0	0	0	0	0	0	0	0	0	0	12	2	1	2	0
BL3	3400	2	6	0	0	0	0	0	0	0	0	0	0	6	2	0	0	0
BL3	3600	1	7	1	0	0	0	0	0	0	0	0	0	5	6	2	0	1
BL3	3600	2	6	0	0	0	0	0	0	0	0	0	0	7	5	0	0	0
BL3	3800	1	5	0	0	0	0	0	0	0	0	0	0	3	4	0	0	0
BL3	3800	2	2	0	0	0	0	0	0	0	0	0	0	11	2	0	0	0
BL3	4000	1	3	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0
BL3	4000	2	10	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0
BL3	4000	3	15	0	0	0	0	0	0	0	0	0	0	9	2	1	0	0
BL3	4000	3	15	0	0	0	0	0	0	0	0	0	0	14	1	1	0	0

TABLE D.3.1

TETRA PGALA DODON POMAD HIBBE HYPER DRIMY PIMEL KUNZE CALLI EUCAL ANGOP LEPTO EPILO HALOR

BL3	0	1	0	0	1	6	0	0	1	0	1	0	36	0	5	0	0
BL3	20	1	0	0	0	11	0	0	1	0	1	0	42	0	3	0	2
BL3	40	1	0	0	0	4	0	0	0	0	0	0	34	0	1	0	3
BL3	60	1	0	0	2	7	0	0	0	0	0	0	38	0	9	0	1
BL3	80	1	0	0	1	21	0	0	1	0	0	0	32	0	2	0	3
BL3	100	1	0	0	2	7	0	0	1	0	0	0	42	0	6	0	2
BL3	118	1	0	0	1	6	0	0	0	0	0	0	41	0	1	0	2
BL3	140	1	0	0	1	6	0	0	0	0	0	0	37	0	2	0	2
BL3	160	1	0	0	3	18	0	0	0	0	0	0	44	0	5	0	2
BL3	180	1	0	0	3	9	0	0	1	0	0	0	38	0	7	0	1
BL3	220	1	0	0	1	24	0	0	2	0	0	0	46	1	4	0	2
BL3	240	1	0	0	0	4	0	0	1	0	0	0	64	0	6	0	4
BL3	260	1	0	0	0	2	0	0	0	1	1	0	55	0	3	0	4
BL3	280	1	0	0	0	2	0	0	0	0	0	0	75	0	4	0	3
BL3	300	1	0	0	0	2	0	0	2	0	0	0	50	0	4	0	2
BL3	320	1	0	0	0	0	0	0	2	0	0	0	35	0	2	0	1
BL3	340	2	0	0	1	0	0	0	2	0	0	0	25	0	2	0	3
BL3	360	1	0	0	0	0	0	0	0	0	0	0	66	0	6	0	3
BL3	380	2	0	0	0	0	0	0	0	0	0	0	24	0	3	0	0
BL3	400	1	0	0	0	0	0	0	0	0	0	0	29	0	2	0	7
BL3	420	2	0	0	0	0	0	0	0	0	0	0	42	0	3	0	2
BL3	440	1	0	0	1	0	0	0	1	0	0	0	22	0	4	0	3
BL3	460	2	0	0	0	0	0	0	0	0	1	0	19	0	3	0	1
BL3	480	1	0	0	0	0	0	0	0	0	0	0	2	0	1	0	0
BL3	400	2	0	0	0	0	0	0	0	0	0	0	11	0	2	0	0
BL3	400	3	0	0	0	0	0	0	0	0	0	0	11	0	0	0	3

TABLE D.3.2

PARAH GRATI UTRIC MYOPO PLANL PLANM COPRO ASPER WAHLE STYLI TUB 1 TUB 2 TUB 3 TUB 4 TUB 5

BL3	0	1	0	0	0	1	0	2	0	0	0	0	2	7	5	1	0
BL3	20	1	0	0	0	0	0	0	0	1	0	0	1	3	6	4	2
BL3	40	1	1	0	0	0	0	1	0	0	0	0	0	1	3	6	1
BL3	60	1	0	0	0	0	0	0	0	0	0	0	0	1	2	2	2
BL3	80	1	0	0	0	0	0	2	0	0	0	0	0	2	4	1	0
BL3	100	1	0	0	0	0	0	2	0	0	0	0	0	2	3	2	0
BL3	118	1	0	0	0	0	0	1	0	0	0	0	0	2	3	1	2
BL3	140	1	1	0	0	1	0	0	0	0	0	0	0	1	4	3	2
BL3	160	1	0	0	0	0	0	0	1	0	0	0	0	5	4	0	1
BL3	180	1	0	0	0	0	0	2	1	1	0	0	0	3	2	3	1
BL3	200	1	0	0	0	0	0	1	1	1	0	0	0	1	2	1	1
BL3	220	1	0	0	0	0	0	1	1	2	0	0	0	3	1	3	1
BL3	240	1	0	0	0	0	0	7	2	0	0	0	0	4	10	4	2
BL3	260	1	1	0	0	1	0	5	2	0	0	0	3	11	15	3	2
BL3	280	1	0	0	0	0	0	5	0	0	0	0	9	11	8	1	1
BL3	300	1	0	0	0	0	0	5	0	0	0	0	8	12	7	0	0
BL3	320	1	0	0	0	0	0	2	0	0	0	0	4	4	3	2	0
BL3	320	2	0	0	0	3	0	6	0	0	0	0	9	14	5	1	1
BL3	340	1	0	0	0	0	0	1	0	0	0	0	5	7	3	1	0
BL3	340	2	0	0	0	0	0	2	0	0	0	0	6	5	3	0	0
BL3	360	1	0	0	0	0	0	1	0	0	0	0	9	5	4	0	0
BL3	360	2	0	0	0	0	0	3	1	0	0	0	1	9	5	1	0
BL3	380	1	0	0	0	0	0	3	0	0	0	0	4	8	0	0	1
BL3	400	2	0	0	0	0	0	0	0	0	0	0	4	5	1	0	0
BL3	400	1	0	0	0	0	0	0	0	0	0	0	4	1	0	0	0
BL3	400	2	1	0	0	0	0	0	0	0	0	0	2	2	0	0	0
BL3	400	3	0	0	0	0	0	2	0	0	0	0	2	5	1	0	0

TABLE D.4

Twynam Cirque Section

Slide Code	Sample Depth (cm)	Pollen Count	Sample Fraction Counted	Pollen Concentration	
				grains/cc	grains/g \pm std. err.
TCA 35	35	279	0.00093 *	150000	134000 \pm 28000
TCA 50	50	213	0.0020 *†	53000	43000 \pm 9100
TCA 90	90	353	0.0021 *	84000	71000 \pm 15000
TCA100	100	465	0.0020 *	116000	88000 \pm 18000
TCA110	110	497	0.0019 *	131000	95000 \pm 20000
TCA125	125	377	0.00091 *	207000	154000 \pm 32000
TCA135	135	648	0.0019 *	171000	130000 \pm 27000
TCA145	145	615	0.0018 *	171000	126000 \pm 26000

* From evenly spaced traverses, 10-20% of slide.

† Sample loss noted during preparation.

TABLE D.4.1

	TYPHA	TRIGL	POA 1	POA 2	POA 3	POA 4	POA 5	POA 6	POA A	CYPER	RESTI	XYRIS	ASPHO	DIANE	ASTEL
TCA 35	0	0	27	33	7	6	0	0	3	23	1	0	1	0	0
TCA 50	0	0	18	22	12	3	0	0	4	15	0	0	0	0	0
TCA 90	2	0	23	37	19	7	1	0	0	14	0	0	0	0	0
TCA 100	0	0	18	48	27	13	0	0	9	6	0	0	0	0	1
TCA 110	1	0	49	33	17	5	0	0	2	8	1	0	0	0	0
TCA 125	1	0	26	29	21	1	1	0	2	6	2	0	0	0	0
TCA 135	2	0	48	53	21	10	4	0	25	6	1	0	0	0	0
TCA 145	1	0	54	52	26	3	1	0	7	6	3	0	0	0	0

TABLE D.4.2

	CASUA	URTIC	GREVI	HAKEA	BANKS	LMAT	EXOCA	AMYEM	RUMEX	POLYG	CENT1	CENT2	CENT3	GYROS	NEDPX
TCA	35	4	0	0	0	0	0	0	0	0	12	1	0	0	1
TCA	50	7	1	0	0	0	0	0	0	0	8	3	0	0	1
TCA	90	43	0	0	0	0	0	0	0	0	28	7	0	0	0
TCA	100	27	3	0	0	0	0	0	0	0	27	6	0	0	0
TCA	110	47	1	0	0	0	0	0	0	0	40	5	0	1	0
TCA	125	50	0	0	0	0	0	0	0	0	26	0	0	3	0
TCA	135	94	0	0	0	0	0	0	0	0	66	0	0	1	0
TCA	145	97	0	0	0	0	0	0	0	0	85	0	1	2	0

TABLE D.4.3

STELL RANUN ATHER CRUCI BURSA ACAEN ACACI HARDE BOSSI TRIFO DAVIE HOVEA PHEBA CORRE ERIOS

TCA	35	0	4	0	4	0	0	0	0	0	0	0	1	0	0	0	0
TCA	50	0	5	0	4	1	0	0	0	0	0	0	0	0	0	0	0
TCA	90	1	0	0	15	0	0	2	0	0	0	0	0	1	0	0	0
TCA	100	0	3	0	62	0	0	0	1	0	0	0	0	0	0	0	0
TCA	110	0	0	0	19	0	0	0	0	0	0	0	0	0	0	0	0
TCA	125	0	1	0	2	0	0	0	0	0	0	0	0	0	0	0	0
TCA	135	0	1	0	2	0	0	2	0	0	0	0	1	0	0	0	0
TCA	145	0	1	0	2	0	0	1	0	0	0	0	3	0	0	0	0

TABLE D.4.4

TETRA PGALA DODON POMAD HIBBE HYPER DRIMY PIMEL KUNZE CALLI EUCAL ANGOP LEPTO EPILO HALOR

TCA	35	0	0	0	0	0	0	1	0	1	0	58	0	3	0	5
TCA	50	0	0	0	0	0	0	3	0	1	0	46	0	2	0	1
TCA	90	0	0	1	0	0	0	2	2	2	0	68	0	3	0	1
TCA	100	0	0	1	1	0	0	2	1	0	0	95	0	4	0	3
TCA	110	0	0	4	0	0	0	3	0	0	0	143	0	1	0	3
TCA	125	0	0	2	0	0	0	0	0	0	0	116	0	2	0	3
TCA	135	0	0	2	0	0	0	2	1	0	0	147	0	7	0	4
TCA	145	0	0	0	0	0	0	0	1	1	0	102	0	10	0	4

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TABLE D.4.5

MYRIO TIEGH HYDRO ACIPH DICHO SCHIZ EPACR EPSEK MONOT CENTA GENTI BORAG ECHIU PROST EUPHR

TCA	35	0	0	2	9	0	2	2	0	0	0	0	0	0	0	0
TCA	50	00	00	00	13	00	2	0	00	00	00	00	00	00	00	00
TCA	90	00	00	00	08	00	1	0	00	00	00	00	00	00	00	00
TCA	100	00	2	00	00	00	00	2	00	1	00	00	00	00	00	00
TCA	110	00	0	00	7	00	00	1	00	00	00	00	00	00	00	00
TCA	125	00	00	00	2	00	00	1	00	00	00	00	00	00	00	00
TCA	135	00	00	00	1	00	00	1	00	00	00	00	00	00	1	00
TCA	145	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0

TABLE D.4.6

PARAH GRATI UTRIC MYOPO PLANL PLANM COPRO ASPER WAHLE STYLI TUB 1 TUB 2 TUB 3 TUB 4 TUB 5

TCA	35	1	0	0	0	0	4	2	0	0	0	23	18	10	0	0
TCA	50	0	0	0	0	0	3	0	0	0	0	12	6	4	1	0
TCA	90	0	0	0	0	0	7	2	0	0	0	18	15	2	0	0
TCA	100	0	0	0	0	0	8	0	0	0	0	25	20	10	3	0
TCA	110	0	0	0	0	0	4	2	1	0	0	23	34	10	1	0
TCA	125	0	0	0	0	0	15	2	0	0	0	20	25	2	1	0
TCA	135	0	0	0	0	0	18	1	0	0	0	37	33	10	1	0
TCA	145	0	0	0	0	0	12	1	0	0	0	61	28	10	4	0

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TABLE D.4.7

LIGUL EWART PODDC DACRY CUPRE PINUS LYCSE LYCFA OPHIO FILIM FILIT F 137 F 156 PELLE CHEIL

TCA	35	0	0	0	0	0	0	0	0	0	0	3	4	0	0	0	0
TCA	50	0	2	0	0	1	0	0	0	0	0	0	1	0	0	0	0
TCA	90	0	5	5	0	3	0	0	0	0	0	3	0	0	0	0	0
TCA	100	0	6	6	0	3	0	0	0	0	0	2	0	0	0	0	1
TCA	110	0	10	9	0	0	0	1	1	0	0	5	1	1	0	0	0
TCA	125	0	9	5	0	0	0	0	0	0	0	1	0	0	0	0	0
TCA	135	1	30	10	0	2	0	0	0	0	0	1	0	0	0	0	0
TCA	145	0	29	2	1	0	0	0	0	0	1	0	0	0	0	0	0

TABLE D.5

Geehi Valley Pollen Traps

Trapping Interval	Dates	Period in years
1	22 May 1970 - 28 Nov. 1970	0.504
2	28 Nov. 1970 - 27 Jan. 1971	0.164
3	27 Jan. 1971 - 26 Apr. 1971	0.244
4	26 Apr. 1971 - 8 July 1971	0.200
5	8 July 1971 - 4 Dec 1971	0.408
6	4 Dec. 1971 - 22 Jan. 1972	0.134
7	22 Jan. 1972 - 28 Mar. 1972	0.181
8	28 Mar. 1972 - 8 June 1972	0.197
9	8 June 1972 - 30 July 1972	0.142
10	30 July 1972 - 8 Oct. 1972	0.192

Site

Slide Code	Trapping Interval	Pollen Count	Sample Fraction Counted	Pollen ₂ grains/cm ² /yr	Deposition grains/cm ² ± std. err.
Bella Vista					
BEV 1	1	25	0.0020	1210	610 ± 140
BEV 2	2	369	0.00013*	830000	136000 ± 31300
BEV 3	3	38	0.0080	950	230 ± 44
BEV 4 1	4	18	0.024	175	35 ± 8
BEV 4 2	4	5	0.0080		
BEV 5	5	205	0.0080	3060	1250 ± 160
BEV 6	6	310	0.020	5630	760 ± 89
BEV 7	7	691	0.0018 *	101000	18300 ± 4200
BEV 8	8	27	0.0080	830	160 ± 35
BEV 9	9	2	0.0080	85	12 ± 9
BEV 10	10	20	0.0080	630	120 ± 29
Claymore Creek Low					
CCL 2	2	222	0.0053 *	12500	2060 ± 480
CCL 3	3	552	0.0040	27500	6720 ± 740
CCL 4	4	86	0.0080	2600	520 ± 77
CCL 5	5	87	0.0080	1300	530 ± 78
CCL 6	6	640	0.0160	14500	1950 ± 210
CCL 7	7	417	0.0080	14000	2540 ± 290
CCL 8	8	86	0.0320	660	130 ± 19
CCL 9	9	6	0.0320	60	9 ± 4
CCL 10	10	150	0.0320	120	230 ± 40

TABLE D.5 (Cont.)

Slide Code	Trapping Interval	Pollen Count	Sample Fraction Counted	Pollen Deposition grains/cm ² /yr	grains/cm ² ± std. err.
Claymore Creek High					
CCH 3	3	502	0.0080	12500	3060 ± 340
CCH 4 1	4	28	0.0240	310	60 ± 11
CCH 4 2	4	13	0.0080		
CCH 5	5	116	0.0080	1730	700 ± 97
CCH 6	6	31	0.0080	1400	190 ± 39
CCH 7	7	411	0.0080	13820	2500 ± 280
CCH 8	8	236	0.0080	7300	1440 ± 170
CCH 9	9	2	0.0080	90	12 ± 9
CCH 10	10	21	0.0080	660	130 ± 31

* From evenly spaced traverses, about 20% of slide.

TABLE D.5.4

TETRA PGALA DODON POMAD HIBBE HYPER DRIMY PIMEL KUNZE CALLI EUCAL ANGOP LEPTO EPILO HALOR

BEV	1	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0
BEV	2	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
BEV	3	0	0	0	0	0	0	0	0	0	0	11	0	0	0	0
BEV	4	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0
BEV	4	2	0	0	0	0	0	0	0	0	0	1	0	0	0	0
BEV	5	0	0	0	0	0	0	0	0	0	0	35	0	0	0	5
BEV	6	0	0	0	0	0	0	0	0	0	0	7	0	0	0	1
BEV	7	16	0	0	0	0	0	0	0	0	0	50	0	1	2	0
BEV	8	0	0	0	0	0	0	0	0	0	0	20	0	8	4	0
BEV	9	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
BEV	10	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
CCL	2	0	0	0	0	0	0	0	0	0	0	9	0	0	0	0
CCL	3	3	0	0	0	0	0	0	0	0	0	153	0	1	3	2
CCL	4	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
CCL	5	0	0	0	0	0	0	0	0	0	0	33	0	0	0	0
CCL	6	0	0	0	0	0	0	0	0	0	0	36	0	0	0	0
CCL	7	1	1	1	1	1	1	1	1	1	1	167	0	1	6	7
CCL	8	2	0	0	0	0	0	0	0	0	0	46	0	0	0	0
CCL	9	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
CCL	10	0	0	0	0	0	0	0	0	0	0	9	0	0	0	0
CCH	3	0	0	0	0	0	0	0	0	0	0	115	0	0	3	0
CCH	4	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
CCH	4	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CCH	4	2	0	0	0	0	0	0	0	0	0	0	0	0	0	1
CCH	5	0	0	0	0	0	0	0	0	0	0	9	0	0	0	2
CCH	6	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0
CCH	7	2	0	0	0	0	0	0	0	0	0	19	0	0	6	0
CCH	8	0	0	0	0	0	0	0	0	0	0	227	0	0	0	0
CCH	9	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
CCH	10	0	0	1	0	0	0	0	0	0	0	3	0	0	0	1

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TABLE D.5.6

PARAH GRATI UTRIC MYOPO PLANL PLANM COPRO ASPER WAHLE STYLI TUB 1 TUB 2 TUB 3 TUB 4 TUB 5

B	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0
B	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B	4	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B	5	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B	10	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C	3	4	0	0	0	0	0	0	0	0	0	0	0	3	7	8
C	4	4	0	0	0	0	0	0	0	0	0	0	0	3	1	0
C	5	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0
C	6	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0
C	7	2	0	0	0	0	0	0	0	0	0	0	0	4	1	0
C	8	0	0	0	0	0	0	0	0	0	0	0	0	6	2	0
C	9	0	0	0	0	0	0	0	0	0	0	0	0	4	5	0
C	10	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0
H	3	1	0	0	0	0	0	0	0	0	0	0	0	3	1	1
H	4	2	0	0	0	0	0	0	0	0	0	0	0	1	0	0
H	5	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
H	6	3	0	0	0	0	0	0	0	0	0	0	0	1	0	0
H	7	1	0	0	0	0	0	0	0	0	0	0	0	2	0	0
H	8	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0
H	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
H	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

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TABLE D.5.8

DICKS HYPOL CULCI ASPLE POLYS GRAMM UNIDE UNKNO SPH N SPH R SPH F SPH P ACRIT BOTRY TSUGA

B	1	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0
B	2	0	0	0	0	0	0	2	1	0	0	0	0	0	0	0	0
B	3	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0
B	4	1	0	0	0	0	0	2	0	0	0	0	0	0	0	1	0
B	5	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
B	6	0	0	0	0	0	0	33	0	0	0	0	0	0	0	0	5
B	7	0	0	0	0	0	0	10	0	0	0	0	0	0	0	0	0
B	8	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	1
B	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6
B	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
C	2	0	0	0	0	0	0	16	3	0	0	0	0	0	0	0	0
C	3	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
C	4	0	0	0	0	0	0	6	0	0	0	0	0	0	0	0	6
C	5	2	0	0	0	0	0	15	0	0	0	0	0	0	0	0	3
C	6	1	0	0	0	0	0	45	1	0	0	0	0	0	0	0	5
C	7	1	0	0	0	0	0	28	0	0	0	0	0	0	0	0	2
C	8	0	0	0	0	0	0	6	0	0	0	0	0	0	0	0	1
C	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
C	10	0	0	0	0	0	0	11	0	0	0	0	0	0	0	0	0
C	3	2	0	0	0	0	0	7	0	0	0	0	0	0	0	0	1
C	4	2	0	0	0	0	0	5	0	0	0	0	0	0	0	0	2
C	5	2	0	0	0	0	0	2	0	0	0	0	0	0	0	0	2
C	6	1	0	0	0	0	0	12	0	0	0	0	0	0	0	0	2
C	7	0	0	0	0	0	0	5	1	0	0	0	0	0	0	0	2
C	8	0	0	0	0	0	0	15	0	0	0	0	0	0	0	0	5
C	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
C	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

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Table D.6 Alpine Area Pollen Traps

Collection No.	Trapping Interval	Period (yrs)
2	26 Nov. 1970 - 21 Jan. 1971	0.156
3	21 Jan. 1971 - 15 Apr. 1971	0.233
4	15 Apr. 1971 - 2 July 1971	0.216
6	18 Nov. 1970 - 21 Jan. 1972	0.178
7	21 Jan. 1972 - 30 Mar. 1972	0.192
8	30 Mar. 1972 - 1 June 1972	0.173

<u>Site</u>					
Slide Code	Collection No.	Pollen Count	Sample Fraction Counted	Pollen Deposition grains/cm ² /yr	grains/cm ² est. ± std.er.
<u>Summit</u>					
SUM 2	2	141	.020	2200	340 ± 45
SUM 3	3	56	.020	590	140 ± 24
SUM 4	4	32	.020	360	80 ± 16
SUM 6	6	441	.020	6030	1070 ± 120
SUM 7	7	114	.020	1450	280 ± 39
SUM 8	8	69	.020	970	170 ± 27
<u>Col</u>					
COL 2	2	9	.0080	350	60 ± 21
COL 3	3	124	.020	1300	300 ± 41
COL 4	4	33	.020	370	80 ± 16
COL 6	6	333	.020	4550	810 ± 94
COL 7	7	167	.010 *	4230	810 ± 120
COL 8	8	71	.020	1000	170 ± 27
<u>Delta</u>					
DEL 3	3	91	.020	950	220 ± 32
DEL 4	4	28	.020	320	70 ± 15
DEL 6	6	321	.0092*	9540	1700 ± 390
DEL 7	7	875	.020	11090	2130 ± 230
DEL 8	8	418	.020	5880	1020 ± 115
<u>Efflux</u>					
EFO 2	2	84	.020	1310	210 ± 31
EFO 3	3	94	.020	980	230 ± 33
EFO 4	4	36	.020	410	90 ± 18
EFO 6	6	381	.020	5210	930 ± 110
EFO 7	7	210	.020	2660	510 ± 63
EFO 8	8	97	.020	1370	240 ± 35

Table D.6 (Cont.)

<u>Site</u>		Collection No.	Pollen Count	Sample Fraction Counted	Pollen Deposition	
Slide Code	grains/cm ² /yr				grains/cm ² est. ± std. err.	
<u>Efflux Roofed</u>						
EFR 3		3	190	.020	1990	460 ± 58
EFR 4		4	38	.020	430	90 ± 17
EFR 6		6	273	.020	3740	660 ± 78
EFR 7		7	283	.020	3590	690 ± 81
EFR 8		8	163	.020	2290	400 ± 51
<u>Hedley Tarn</u>						
HED 3		3	109	.020	1140	270 ± 38
HED 4		4	20	.020	230	50 ± 12
HED 6		6	420	.020	5740	1020 ± 115
HED 7		7	184	.020	2330	450 ± 57
HED 8		8	49	.020	690	120 ± 21

* From evenly spaced traverses, about 50% of slide.

TABLE D-6-2

CASUA URTIC GREVI HAKEA BANKS LOMAT EXOCA AMYEM RUMEX POLYG CENT1 CENT2 CENT3 GYROS NEOPX

SUM	2	0	0	0	0	0	0	0	0	7	0	2	0	0	0	0
SUM	3	0	0	0	0	0	0	0	0	9	0	5	0	0	0	0
SUM	4	0	0	0	0	0	0	0	0	7	0	4	1	0	0	0
SUM	6	1	0	15	0	0	0	0	0	64	0	13	2	0	0	0
SUM	7	0	2	0	0	0	0	0	0	12	0	3	1	0	0	0
SUM	8	0	0	0	0	0	0	0	0	5	0	1	0	0	0	0
COL	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
COL	3	1	0	0	0	0	0	0	0	15	0	6	2	0	0	1
COL	4	0	0	0	0	0	0	0	0	5	0	4	1	0	0	0
COL	6	2	0	0	0	0	0	0	0	37	0	4	1	0	0	0
COL	7	0	0	0	0	0	0	0	0	21	0	5	0	0	0	0
COL	8	1	0	0	0	0	0	0	0	4	0	3	1	0	0	0
DEL	3	0	1	0	0	0	0	0	0	11	0	6	1	0	0	0
DEL	4	1	0	0	0	0	0	0	0	4	0	3	0	0	0	0
DEL	6	1	0	5	0	0	0	0	0	21	0	15	1	0	0	0
DEL	7	1	0	1	0	0	0	0	0	31	0	10	1	0	0	2
DEL	8	0	0	0	0	0	0	0	0	6	0	0	1	0	0	0
EFO	2	3	0	0	0	0	0	0	0	19	0	4	0	0	0	0
EFO	3	4	0	0	0	0	0	0	0	12	0	4	1	0	0	0
EFO	4	1	0	0	0	0	0	0	0	1	0	3	4	0	0	0
EFO	6	0	0	0	0	0	0	0	0	48	0	6	5	0	0	0
EFO	7	1	0	0	0	0	0	0	0	21	0	6	5	0	0	0
EFO	8	1	0	0	0	0	0	0	0	0	0	4	2	0	0	0
EFR	3	1	2	0	0	0	0	0	0	22	0	4	1	0	0	1
EFR	4	1	1	0	0	0	0	0	0	1	0	3	3	0	0	0
EFR	6	0	2	0	0	0	0	0	0	13	0	4	3	0	0	0
EFR	7	0	1	0	0	0	0	0	0	4	0	2	2	0	0	0
EFR	8	0	0	0	0	0	0	0	0	12	0	7	3	0	0	0
HED	3	0	0	0	0	0	0	0	0	24	0	3	0	0	0	0
HED	4	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
HED	6	7	4	0	0	0	0	0	0	56	0	13	5	0	0	0
HED	7	0	1	0	0	0	0	0	0	21	0	5	3	0	0	0
HED	8	1	0	0	0	0	0	0	0	2	0	0	0	0	0	0

TABLE D*6*4

TETRA PGALA DODON POMAD HIBBE HYPER DRIMY PIMEL KUNZE CALLI EUCAL ANGOP LEPTO EPILO HALOR

SUM	2	3	0	2	3	0	0	1	0	1	0	12	0	0	0	1
SUM	3	0	0	0	0	0	0	0	0	0	0	21	0	1	0	0
SUM	4	0	0	0	0	0	0	0	0	0	0	4	0	1	0	0
SUM	6	0	0	4	2	0	0	0	0	0	0	28	0	3	0	0
SUM	7	0	0	2	0	0	0	0	0	0	0	28	0	0	0	1
SUM	8	0	0	0	0	0	0	0	2	0	0	14	0	1	0	0
COL	2	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
COL	3	0	0	0	0	0	0	0	0	0	0	17	0	0	0	0
COL	4	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
COL	6	0	0	0	7	1	0	1	0	0	0	25	0	2	0	0
COL	7	0	0	0	0	0	0	0	0	0	0	11	0	0	0	2
COL	8	0	0	1	0	0	0	0	0	1	0	22	0	0	0	0
DEL	3	0	0	0	0	0	0	0	0	0	0	41	0	2	0	0
DEL	4	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0
DEL	6	1	0	0	2	6	0	0	0	0	0	56	0	1	0	2
DEL	7	0	0	3	0	0	0	0	0	0	0	25	0	12	0	0
DEL	8	0	0	0	0	0	0	0	0	0	0	15	0	2	0	0
EFO	2	0	0	0	1	0	0	0	0	0	0	7	0	0	0	0
EFO	3	0	0	0	0	0	0	0	0	0	0	37	0	2	0	0
EFO	4	0	0	0	0	0	0	0	0	0	0	7	0	0	0	0
EFO	6	0	0	5	4	0	0	1	0	0	0	32	0	0	0	3
EFO	7	0	0	2	0	0	0	0	0	2	0	40	0	0	0	1
EFO	8	0	0	0	0	0	0	0	0	0	0	22	0	0	0	1
EFR	3	1	0	1	5	0	0	1	0	0	0	26	0	9	0	0
EFR	4	0	0	0	0	0	0	0	0	0	0	6	0	0	0	0
EFR	6	0	0	8	2	0	0	0	0	0	0	17	0	3	0	5
EFR	7	0	0	1	0	0	0	0	1	56	0	121	0	0	0	0
EFR	8	0	0	1	0	0	0	0	0	0	0	51	0	0	0	0
HED	3	0	0	2	0	0	0	0	0	0	0	32	0	0	0	0
HED	4	0	0	1	0	0	0	0	0	0	0	3	0	0	0	0
HED	6	0	0	2	5	0	0	0	0	0	0	48	0	7	0	0
HED	7	0	0	2	0	0	0	0	1	0	0	20	0	7	0	2
HED	8	0	0	0	0	0	0	0	0	4	0	3	0	0	0	0

TABLE D-6.6

PARAM GRATI UTRIC MYOPO PLANL PLANM COPRO ASPER WAHLE STYLI TUB 1 TUB 2 TUB 3 TUB 4 TUB 5

SUM 2	0	0	0	0	0	0	0	0	0	0	0	1	8	2	0	0
SUM 3	0	0	0	0	1	0	0	0	0	0	0	0	1	1	0	0
SUM 4	0	0	0	0	1	0	0	0	0	0	0	0	1	1	0	0
SUM 6	0	0	0	0	2	1	0	0	0	0	0	0	10	19	0	2
SUM 7	0	0	0	0	1	0	0	0	0	0	0	0	2	3	2	0
SUM 8	0	0	0	0	1	0	0	0	0	0	0	0	2	3	3	0
COL 2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
COL 3	0	0	0	0	0	0	0	0	0	0	0	1	15	49	2	0
COL 4	0	0	0	0	0	0	0	0	0	0	0	0	4	10	3	0
COL 6	1	0	0	0	0	0	0	0	0	0	0	0	5	1	1	0
COL 7	0	0	0	0	0	1	1	1	0	0	0	0	2	33	10	5
COL 8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0
DEL 3	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0
DEL 4	0	0	0	0	0	0	0	0	0	0	0	0	3	5	1	0
DEL 6	1	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0
DEL 7	0	0	0	0	0	0	0	0	0	0	0	3	1	6	1	0
DEL 8	0	0	0	0	2	0	0	0	0	0	0	0	1	10	4	6
EFO 2	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
EFO 3	1	0	0	0	0	0	0	0	0	0	0	0	2	1	0	0
EFO 4	0	0	0	0	0	0	0	0	0	0	0	0	0	6	1	0
EFO 6	0	0	0	0	5	0	0	0	0	0	0	0	4	4	0	1
EFO 7	0	0	0	0	1	0	0	0	0	0	0	0	4	1	4	5
EFO 8	0	0	0	0	1	0	0	0	0	0	0	0	2	4	6	1
EFR 3	1	0	0	0	0	0	0	0	0	0	0	0	5	2	1	1
EFR 4	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0
EFR 6	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0
EFR 7	0	0	0	0	0	0	0	0	0	0	0	0	0	3	3	0
EFR 8	0	0	0	0	0	0	0	0	0	0	0	0	1	1	2	0
HED 3	0	0	0	0	0	0	0	0	0	0	0	1	4	9	2	1
HED 4	0	0	0	0	0	0	0	0	0	0	0	0	2	7	0	0
HED 6	0	0	0	0	0	0	0	0	0	0	0	0	4	6	1	0
HED 7	0	0	0	0	0	0	0	0	0	0	0	0	1	0	6	5
HED 8	0	0	0	0	0	0	0	0	0	0	0	1	1	1	18	4

48
254

TABLE D*6*7

LIGUI FWART PODOC DACRY CUPRE PINUS LYCSE LYCFA OPHIO FILIM FILIT F 137 F 156 PELLE CHEIL

SUM	2	2	0	0	0	0	2	0	0	0	0	0	0	0	0	0
SUM	3	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00
SUM	4															
SUM	6	12	00	20	00	00	20	00	00	00	10	00	00	00	00	00
SUM	7	00	00	10	00	00	30	00	00	00	00	00	00	00	00	00
SUM	8	00	00	00	00	00	00	00	00	00	10	00	00	00	00	00
COL	2	10	00	00	00	00	30	00	00	00	00	00	00	00	00	00
COL	3	10	00	00	00	00	00	00	00	00	00	00	00	00	00	00
COL	4															
COL	6	20	00	00	00	00	60	00	00	00	00	00	00	00	00	00
COL	7	10	00	00	00	00	30	00	00	00	00	00	00	00	00	00
COL	8	10	00	00	00	00	00	00	00	00	00	00	00	00	00	00
DEL	3	10	00	00	00	00	20	00	00	00	30	00	00	00	00	00
DEL	4	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00
DEL	6	20	10	00	00	00	60	00	00	00	10	00	00	00	00	00
DEL	7	20	00	00	00	00	90	00	00	00	10	00	00	00	00	00
DEL	8	30	00	00	00	00	10	00	00	00	20	00	00	00	00	00
EFO	2	10	10	00	00	00	00	00	00	00	00	00	00	00	00	00
EFO	3	00	00	30	00	00	20	00	00	00	00	00	00	00	00	00
EFO	4															
EFO	6	20	00	00	00	00	80	00	00	00	10	00	00	00	00	00
EFO	7	00	00	00	10	00	20	00	00	00	00	00	00	00	00	00
EFO	8	10	00	00	40	00	00	00	00	00	20	00	00	00	00	00
EFR	3	10	00	00	00	00	00	00	00	00	30	00	00	00	00	00
EFR	4	00	00	00	00	00	10	00	00	00	10	00	00	00	00	00
EFR	6	30	00	00	00	00	50	00	00	00	10	00	00	00	00	00
EFR	7	10	00	00	10	00	30	00	00	00	00	00	00	00	00	00
EFR	8	10	20	00	00	00	20	00	00	00	00	00	00	00	00	00
HED	3	10	10	00	00	00	20	00	00	00	10	00	00	00	00	00
HED	4	00	00	00	00	00	00	00	00	00	00	00	00	00	00	20
HED	6	00	10	10	00	00	50	00	00	00	30	00	00	00	00	00
HED	7	10	00	10	00	00	90	00	00	00	10	00	00	00	00	00
HED	8	00	00	00	00	00	00	00	00	10	00	00	00	00	00	00

Table D.7

Snow Cores

Date, Code	Site/ Section	Depth (cm)	Pollen Count	Pollen content		
				grains/ ml water equiv.	Grains/ cc snow	grains/ cm ² est. ± std. err.
<u>24-25 Oct. 1970</u>						
SN70 1-1	1/1	0-76	318	10.4	6.1	465±54
SN70 1-2	1/2	76-152	127*	16.3	9.8	743±180
SN70 1-3	1/3	152-229	160	5.2	3.0	234±30
	1/4	229-254	@			
						total >1442±190
SN70 2-1	2/1	0-76	105	2.3	2.0	154±22
SN70 2-2	2/2	76-152	26	0.6	0.5	38±8
						total 192±23
SN70 3-1	3/1	0-76	127	4.7	2.4	186±25
SN70 3-2	3/2	76-152	39	1.5	0.8	57±11
	3/3	152-191	@			
						total >243±27
SN70 4-1	4/1	0-76	153	5.1	2.9	224±29
SN70 4-2	4/2	76-152	93	3.3	1.8	136±20
	4/3	152-208	@			
						total >360±35
<u>17-18 Nov. 1971</u>						
SN71 1-1	1/1	0-76	241 *	29.2	17.5	1330±310
SN71 1-2	1/2	76-122	123	6.5	3.9	180±25
						total 1510±310
SN71 2-1	2/1	0-76	293 *	41.7	25.0	1904±440
SN71 2-2	2/2	76-152	51	1.7	1.0	75±13
SN71 2-3	2/3	152-216	334 *	28.8	17.3	1110±260
						total 3089±510
SN71 3-1	3/1	0-76	238 *	21.8	13.1	994±230
SN71 3-2	3/2	76-152	250	8.0	4.8	365±44
SN71 3-3	3/3	152-180	3	0.2	0.1	4±2
						total 1363±234
SN71 4-1	4/1	0-76	254 *	19.8	17.8	1350±315
SN71 4-2	4/2	76-152	62	1.3	1.2	91±15
						total 1441±315

@ Not counted because of observed soil contamination.

* Counted by traversing approximately 20% of slide.

† From measured core densities in 1970, estimated in 1971.

TABLE D-7-1

		TYPHA	TRIGL	POA 1	POA 2	POA 3	POA 4	POA 5	POA 6	POA A	CYPER	RESTI	XYRIS	ASPHO	DIANE	ASTEL
SN70	1-1	0	0	5	54	41	17	2	0	0	7	0	0	0	0	0
SN70	1-2	0	0	3	8	17	12	2	0	0	1	0	0	0	0	0
SN70	1-3	0	0	2	22	26	10	0	0	0	2	0	0	0	0	0
SN70	2-1	0	0	1	9	6	12	1	0	0	0	0	0	0	0	0
SN70	2-2	0	0	0	2	0	1	0	0	0	0	0	0	0	0	0
SN70	3-1	0	0	1	7	10	19	1	0	0	1	0	0	0	0	0
SN70	3-2	0	0	1	1	3	2	0	0	0	3	0	0	0	0	0
SN70	4-1	0	0	3	20	20	19	2	0	0	0	0	0	0	0	0
SN70	4-2	0	0	2	9	7	5	0	0	0	3	0	0	0	0	0
SN71	1-1	0	0	5	13	29	18	0	0	0	5	0	0	0	0	0
SN71	1-2	0	0	0	2	0	3	0	0	0	1	0	0	0	0	0
SN71	2-1	0	0	3	9	11	15	2	0	0	1	1	0	0	0	0
SN71	2-2	0	0	3	6	3	2	0	0	0	0	0	0	0	0	0
SN71	2-3	0	0	5	11	25	30	2	0	0	3	0	0	0	0	0
SN71	3-1	0	0	3	9	17	15	0	0	0	3	0	0	0	0	0
SN71	3-2	0	0	4	6	11	34	0	0	0	1	0	0	0	0	0
SN71	3-3	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
SN71	4-1	0	0	10	10	18	16	5	0	0	0	1	0	0	0	0
SN71	4-2	0	0	0	6	4	1	0	0	0	1	0	0	0	0	1

TABLE D.7.2

	CASUA	URTIC	GREVI	HAKEA	BANKS	LOMAT	EXOCA	AMYEM	RUMEX	POLYG	CENT1	CENT2	CENT3	GYROS	NEOPX
SN70	1-1	4	1	0	0	0	0	0	5	0	10	11	0	1	0
SN70	1-2	3	0	0	0	0	0	0	9	0	9	6	0	2	0
SN70	1-3	4	0	0	0	0	0	0	9	0	6	6	0	0	0
SN70	2-1	2	1	0	0	0	0	0	7	0	7	15	0	1	0
SN70	2-2	1	0	0	0	0	0	0	1	0	1	6	0	1	0
SN70	3-1	4	0	0	0	0	0	0	17	0	3	4	0	2	0
SN70	3-2	0	0	0	0	0	0	0	2	0	0	3	0	0	0
SN70	4-1	4	0	0	0	0	0	0	7	0	2	3	0	2	0
SN70	4-2	5	0	1	0	0	0	0	3	0	6	3	0	2	0
SN71	1-1	4	1	0	0	0	0	0	15	0	14	14	0	1	0
SN71	1-2	0	1	0	0	0	0	0	63	1	6	2	2	0	0
SN71	2-1	7	0	0	0	0	1	0	10	1	30	17	2	0	0
SN71	2-2	1	0	0	0	0	0	0	2	0	2	2	0	0	1
SN71	2-3	4	0	0	0	0	0	0	6	0	17	20	0	1	0
SN71	3-1	1	0	0	0	0	0	0	6	0	14	11	0	2	0
SN71	3-2	1	1	0	0	0	0	0	8	0	16	9	0	1	0
SN71	3-3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SN71	4-1	3	1	0	0	0	0	0	5	0	14	10	3	1	0
SN71	4-2	2	0	0	0	0	0	0	2	0	3	1	0	0	0

TABLE D.7.3

STELI PANUN ATHER CRUCI BURSA ACAEN ACACI HARDE BOSSI TRIFO DAVIE HOVEA PHEBA CORRE ERIOS

SN70 1-1	0	0	0	3	0	0	3	0	0	0	0	0	1	0	0	0
SN70 1-2	00	00	00	1	00	00	1	00	00	00	00	00	00	00	00	00
SN70 1-3	00	00	00	2	00	00	3	00	00	00	00	00	00	00	00	00
SN70 2-1	00	00	00	1	00	00	3	00	00	00	00	00	00	00	00	00
SN70 2-2	00	00	00	0	00	00	1	00	1	00	00	00	00	00	00	00
SN70 3-1	00	00	00	0	00	00	3	00	00	00	00	00	00	00	00	00
SN70 3-2	00	00	00	0	00	00	0	00	00	00	00	00	00	00	00	00
SN70 4-1	00	00	00	1	00	00	1	00	00	00	00	00	00	00	00	00
SN70 4-2	00	00	00	1	00	00	1	00	00	00	00	00	00	00	00	00
SN71 1-1	00	00	00	0	00	00	0	1	00	00	00	00	00	00	00	00
SN71 1-2	00	00	00	0	00	00	2	00	00	00	00	2	00	00	00	00
SN71 2-1	00	00	00	1	00	00	1	2	00	00	00	00	00	00	00	00
SN71 2-2	00	00	00	0	00	00	4	4	00	00	00	00	00	1	00	00
SN71 2-3	00	00	00	0	00	00	3	3	00	00	1	00	00	00	00	00
SN71 3-1	00	00	00	1	00	00	3	3	1	00	00	1	00	00	00	00
SN71 3-2	00	00	00	1	00	00	0	0	00	00	00	1	00	00	00	00
SN71 3-3	00	00	00	0	00	00	2	0	00	00	00	00	00	00	00	00
SN71 4-1	00	00	00	0	00	00	2	0	00	00	00	00	00	00	00	00
SN71 4-2	0	0	0	2	0	0	0	0	1	0	0	0	0	0	0	0

TABLE D.7.4

TETRA PGALA NODON POMAD HIBBE HYPER PRIMY PIMEL KUNZE CALLI EUCAL ANGOP LEPTO EPILO HALOR

SN70	1-1	0	0	7	1	0	0	0	0	3	0	0	17	0	2	0	2
SN70	1-2	0	0	1	0	0	0	0	0	0	0	0	2	1	0	0	5
SN70	1-3	0	0	1	1	0	0	0	0	0	0	0	6	0	2	0	4
SN70	2-1	0	0	1	0	0	0	0	0	0	0	0	5	0	1	0	1
SN70	2-2	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
SN70	3-1	0	0	5	0	0	0	0	0	0	0	0	3	0	0	0	1
SN70	3-2	0	0	0	0	0	0	0	0	0	0	0	6	0	1	0	2
SN70	4-1	0	0	6	0	0	0	0	0	0	0	0	6	0	2	0	6
SN70	4-2	0	0	1	0	0	0	0	0	0	0	0	5	0	0	0	0
SN71	1-1	0	0	3	0	0	0	0	0	1	0	0	27	0	0	0	2
SN71	1-2	0	0	0	0	0	0	0	0	3	0	0	7	0	0	0	1
SN71	2-1	0	0	12	0	0	0	0	0	0	0	0	11	0	1	0	2
SN71	2-2	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	1
SN71	2-3	0	0	16	1	0	0	2	0	0	0	0	27	0	1	0	5
SN71	3-1	0	0	6	0	0	0	0	0	0	0	0	18	0	0	0	4
SN71	3-2	0	0	14	0	0	0	0	1	0	0	0	12	0	1	0	3
SN71	3-3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SN71	4-1	0	0	9	2	0	0	0	0	0	0	0	25	0	2	0	2
SN71	4-2	0	0	1	0	0	0	0	0	0	0	0	3	0	0	0	0

TABLE D.7.6

PARAM	RATI	UTRIC	MYOPO	PLANL	PLANM	COPRO	ASPER	WAHLE	STYLI	TUB 1	TUB 2	TUB 3	TUB 4	TUB 5
SN70 1-1	2	0	0	0	3	0	0	0	0	1	22	12	9	2
SN70 1-2	0	0	0	1	1	1	0	0	0	1	2	4	0	0
SN70 1-3	0	0	0	0	2	0	0	0	0	4	2	4	2	0
SN70 2-1	0	0	0	0	1	0	0	0	0	1	6	4	1	0
SN70 2-2	0	0	0	1	0	0	0	0	0	1	2	2	0	0
SN70 3-1	0	0	0	0	1	0	0	0	0	0	1	5	0	0
SN70 3-2	0	0	0	0	0	0	0	0	0	0	1	1	0	0
SN70 4-1	0	0	0	1	3	0	0	0	0	3	2	4	1	0
SN70 4-2	0	0	0	1	0	3	0	0	0	3	4	3	0	0
SN71 1-1	0	0	0	0	1	3	0	0	0	14	41	3	0	0
SN71 1-2	0	0	0	0	0	0	0	0	0	1	10	4	0	1
SN71 2-1	0	0	0	0	2	1	0	0	0	8	67	33	2	0
SN71 2-2	0	0	0	0	3	0	0	0	0	0	9	1	0	0
SN71 2-3	0	0	0	1	0	2	0	0	0	10	55	30	2	0
SN71 3-1	1	0	0	0	0	0	0	0	0	13	67	15	1	0
SN71 3-2	0	0	0	1	0	0	0	0	0	16	40	16	1	0
SN71 3-3	0	0	0	0	0	0	0	0	0	0	0	2	0	0
SN71 4-1	1	0	0	2	0	0	0	0	0	14	41	8	0	0
SN71 4-2	0	0	0	0	0	0	0	0	0	3	12	4	2	0

TABLE D.7.8

DICKS WYPOL CULCI ASPLE POLYS GRAMM UNIDE UNKNO SPH W SPH R SPH F SPH P ACRIT BOTRY TSUGA

SN70	1-1	4	0	0	0	0	0	0	18	0	0	0	0	0	0	0	0
SN70	1-2	0	0	0	0	0	0	0	6	0	0	0	0	0	0	0	0
SN70	1-3	1	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0
SN70	2-1	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0
SN70	2-2	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
SN70	3-1	2	0	0	0	0	0	0	4	1	0	0	0	0	0	0	0
SN70	3-2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SN70	4-1	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0
SN70	4-2	1	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0
SN71	1-1	1	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0
SN71	1-2	0	0	0	0	0	0	0	9	0	0	0	0	0	0	0	0
SN71	2-1	0	0	0	0	0	0	0	8	0	0	0	0	0	0	0	0
SN71	2-2	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0
SN71	2-3	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0
SN71	3-1	1	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0
SN71	3-2	1	0	0	0	0	0	0	9	0	0	0	0	0	0	0	0
SN71	3-3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SN71	4-1	0	0	0	0	0	0	0	9	0	0	0	0	0	0	0	0
SN71	4-2	0	0	0	0	0	0	0	4	1	0	0	0	0	0	0	0

Table D.8 Lake Sediment Traps

Collection No.	Trapping Interval	Period (yrs)
3	12 Feb. 1971 - 24 Apr. 1971	0.195
6	24 Apr. 1971 - 21 Jan. 1972	0.745
7	21 Jan. 1972 - 3 Apr. 1972	0.200

<u>Site</u>					
Slide Code	Collection No.	Pollen Count	Sample Fraction Counted	Pollen Grains/cm ² /yr	Deposition grains/cm ² est. ± std. error
<u>Blue Lake West</u>					
LWB 3	3	149	0.0020	4750	930±120
LWB 6	6	233	0.000092*	42200	31500±7400
LWB 7	7	218	0.0010 *	13200	2630±620
<u>Blue Lake South</u>					
LSB 3	3	163	0.0060 *	1730	340±80
LSB 6	6	277	0.00021 *	21920	16300±3800
LSB 7	7	187	0.020	580	116±15
<u>Blue Lake Central Lower</u>					
LMB 3	3	204	0.020	650	130±16
LMB 6	6	208	0.00018 *	18870	14060±3300
LMB 7	7	223	0.0012 *	11960	2390±560
<u>Blue Lake Central Upper</u>					
LMT 3	3	404	0.020	1290	250±30
LMT 6	6	255	0.00032 *	13300	9900±2300
LMT 7	7	119	0.00097 *	7650	1530±370
<u>Blue Lake East</u>					
LEB 3	3	4 [†]	0.020	13	2.5±1
LEB 6	6	364	0.00039 *	15390	11460±2600
LEB 7	7	244	0.0047 *	2700	540±130

† Loss during recovery.

* Counted by traversing about 20% of slide.

TABLE D.P.1

		TYPH _A	TRIGL	POA 1	POA 2	POA 3	POA 4	POA 5	POA 6	POA A	CYPER	RESTI	XYRIS	ASPHO	DIANE	ASTEL
LWB	3	0	0	4	19	17	15	1	0	0	4	0	0	0	0	0
LWB	6	00	00	4	39	28	8	00	00	20	9	00	00	00	00	1
LWB	7	00	00	7	37	16	4	00	00	16	8	1	00	00	1	00
LSB	3	00	00	0	11	16	10	00	00	14	5	1	00	1	00	00
LSB	6	00	00	7	33	28	16	2	00	10	9	1	00	00	00	00
LSB	7	00	00	10	29	23	12	00	00	10	5	00	00	00	00	00
LMB	3	00	00	5	21	24	5	00	00	0	4	00	00	00	00	00
LMB	6	00	00	7	45	24	13	2	00	1	5	00	00	00	00	00
LMB	7	00	00	7	25	27	11	1	00	18	9	00	00	00	00	00
LMT	3	3	00	7	54	34	8	2	00	1	1	2	00	00	00	00
LMT	6	00	00	8	26	23	9	2	00	28	6	00	00	00	00	00
LMT	7	00	00	4	11	18	3	00	00	13	1	00	00	00	00	00
LEB	3	00	00	0	0	0	0	00	00	0	0	00	00	00	00	00
LEB	6	00	00	10	50	55	17	1	00	20	14	2	00	00	00	00
LEB	7	0	0	7	35	28	8	0	0	29	6	0	0	2	0	0

CASUA URTIC GREVI HAKEA BANKS LOMAT EXOCA AMYEM RUMEX POLYG CENT1 CENT2 CENT3 GYROS NEOPX

LWB	3	4	1	0	0	0	0	0	0	1	0	5	0	0	1	0
LWB	6	2	00	1	00	00	00	00	00	8	00	9	5	00	0	1
LWB	7	1	00	00	00	00	00	00	00	7	00	9	1	00	1	00
LSB	3	2	00	00	00	00	00	00	00	9	00	5	8	00	1	00
LSB	6	8	00	00	00	00	00	00	00	13	00	5	3	00	1	00
LSB	7	6	00	00	00	00	00	00	00	7	00	5	2	00	00	00
LMB	3	11	00	00	00	00	00	00	00	3	00	11	4	00	00	1
LMB	6	5	00	00	00	00	00	00	00	6	00	2	4	00	00	00
LMB	7	2	00	00	00	00	00	00	00	15	00	4	5	1	1	1
LMT	3	11	00	00	00	00	00	00	00	15	00	20	7	1	00	00
LMT	6	3	00	00	00	00	00	1	00	15	00	13	1	00	00	1
LMT	7	00	00	00	00	00	00	00	00	5	00	1	1	00	00	2
LEB	3	00	00	00	00	00	00	00	00	0	00	0	0	00	00	00
LEB	6	10	00	00	00	00	00	00	00	10	00	10	7	00	2	00
LEB	7	5	00	00	00	00	00	00	00	15	00	10	3	00	0	1

TABLE D.B.2

STELI PANUN ATHER CRUCI BURSA ACAEN ACACI HARDE BOSSI TRIFO DAVIE HOVEA PHEBA CORRE ERIOS

LWB	3	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0
LWB	6	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
LWB	7	0	1	0	3	1	0	1	0	0	0	0	0	0	0	0
LSB	3	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0
LSB	6	0	4	0	0	0	0	1	0	0	0	0	0	0	0	0
LSB	7	0	0	0	1	0	0	0	0	0	1	0	0	0	1	0
LMB	3	0	1	0	1	0	0	0	0	0	0	0	0	1	0	0
LMB	6	0	0	0	3	0	0	0	1	0	0	0	0	0	0	1
LMB	7	0	0	2	1	0	0	1	0	0	0	0	0	0	0	1
LMT	3	0	2	0	4	0	1	1	0	0	0	0	0	0	1	0
LMT	6	0	0	0	1	1	0	1	4	0	0	0	0	0	0	0
LMT	7	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
LEB	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LEB	6	0	3	0	1	0	0	3	0	0	0	0	0	2	0	0
LEB	7	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0

TETRA PGALA DODON POMAD HIBBE HYPER DRIMY PIMEL KUNZE CALLI EUCAL ANGOP LEPTO EPILO HALOR

LWB	3	0	0	1	0	0	0	0	0	0	0	30	0	4	0	3
LWB	6	0	0	2	0	0	0	0	0	0	0	31	0	5	0	0
LWB	7	0	0	1	0	1	0	1	0	0	0	37	0	7	0	2
LSB	3	0	0	0	0	0	0	0	0	0	0	25	0	4	0	1
LSB	6	1	0	4	2	0	0	1	0	0	0	33	0	2	0	1
LSB	7	0	0	0	1	0	0	0	0	0	0	30	0	4	0	3
LMB	3	0	0	1	0	0	0	0	0	0	0	41	0	7	0	2
LMB	6	0	0	1	0	0	0	0	0	0	0	33	0	1	0	1
LMB	7	0	0	1	0	0	0	0	0	0	0	34	0	4	0	1
LMT	3	0	0	2	0	0	0	1	1	1	0	112	0	4	0	5
LMT	6	1	0	4	1	0	0	2	0	0	0	32	0	4	0	0
LMT	7	0	0	0	0	0	0	0	0	0	0	18	0	1	0	0
LEB	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LEB	6	0	0	2	2	0	0	1	0	0	0	49	0	2	0	1
LEB	7	0	0	3	0	0	0	0	0	0	0	33	0	5	0	2

TABLE D*8*3

MYRIO TIEGH HYDRO ACIPH DICHO SCHIZ EPACR EPSEK MONOT CENTA GENTI BORAG ECHIU PROST EUPHR

LWB	3	0	1	1	2	0	0	1	0	0	0	0	0	0	0	0
LWB	6	00	00	00	6	000	1	1	00	00	00	00	00	2	00	00
LWB	7	00	00	2	4	000	1	0	00	00	00	00	00	00	00	00
LSB	3	00	00	00	3	000	00	2	00	00	00	00	00	00	00	00
LSB	6	00	00	00	4	000	00	1	00	00	00	00	00	1	00	00
LSB	7	000	00	2	3	1	00	1	00	00	00	00	00	00	00	00
LMB	3	00	00	00	4	1	00	0	1	1	00	00	00	00	00	00
LMB	6	00	00	00	1	000	00	1	00	00	00	00	00	1	00	00
LMB	7	00	00	00	4	000	1	1	00	00	00	00	00	00	00	00
LMT	3	00	00	1	6	1	00	3	00	00	00	3	00	00	00	00
LMT	6	00	00	2	2	000	00	0	00	00	00	00	00	00	00	00
LMT	7	000	1	00	4	000	00	1	00	00	00	00	00	00	00	00
LEB	3	00	00	00	0	000	1	0	00	00	00	00	00	00	00	00
LEB	6	00	00	4	3	000	00	3	00	00	00	00	00	00	00	00
LEB	7	00	00	00	2	000	1	1	00	00	00	00	00	00	00	00

PARAH GRATI UTRIC MYOPO PLANL PLANM COPRO ASPER WAHLE STYLI TUB 1 TUB 2 TUB 3 TUB 4 TUB 5

LWB	3	0	0	0	0	1	0	0	0	0	0	1	3	6	0	0
LWB	6	1	00	00	00	00	00	00	00	00	00	3	11	5	1	00
LWB	7	1	00	1	00	00	3	00	00	00	00	1	9	5	1	00
LSB	3	00	00	00	00	1	00	00	00	00	00	1	3	10	3	00
LSB	6	00	00	00	00	2	1	00	00	00	00	4	15	9	1	00
LSB	7	00	00	00	00	00	1	00	00	00	00	00	5	3	3	00
LMB	3	00	00	00	00	00	5	1	00	00	00	2	14	8	8	1
LMB	6	00	00	00	1	1	00	00	00	00	00	2	17	3	00	00
LMB	7	00	00	00	1	1	00	00	00	00	00	3	5	10	1	1
LMT	3	00	00	00	00	2	2	00	00	00	00	6	13	15	10	1
LMT	6	00	00	00	00	3	00	00	00	00	00	2	17	5	4	1
LMT	7	1	00	00	00	00	00	00	00	00	00	3	5	4	2	00
LEB	3	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00
LEB	6	00	00	00	00	00	00	00	00	00	00	5	32	9	2	00
LEB	7	00	00	00	00	00	2	00	00	00	00	4	10	4	2	00

TABLE D.8.4

	LIGUI	FWART	PODOC	DACRY	CUPRE	PINUS	LYCSE	LYCFA	OPHIO	FILIM	FILIT	F 137	F 156	PELLE	CHEIL
LWB 3	0	1	0	0	0	4	0	0	0	4	1	0	0	0	0
LWB 6	00	1	00	00	6	3	00	00	00	1	1	00	00	00	2
LWB 7	00	00	00	00	00	1	00	00	00	8	00	00	00	00	00
LSB 3	00	00	00	00	00	00	00	1	00	3	00	00	00	00	00
LSB 6	00	00	00	00	7	3	00	00	00	2	00	00	00	00	1
LSB 7	00	00	1	00	00	2	1	00	00	5	00	00	00	00	00
LMB 3	1	1	00	00	00	00	00	00	1	1	00	00	00	00	00
LMB 6	1	00	00	00	00	4	00	00	00	2	00	00	00	00	1
LMB 7	00	00	00	00	00	2	00	1	00	3	2	00	00	00	00
LMT 3	1	2	00	00	00	3	00	3	00	7	1	00	00	00	3
LMT 6	0	00	00	00	00	5	00	00	00	4	1	00	00	00	00
LMT 7	1	1	00	00	00	2	00	00	00	6	00	00	00	00	00
LEB 3	0	00	00	00	00	00	00	00	00	1	00	00	00	00	00
LEB 6	1	00	00	00	00	8	00	00	00	5	2	00	00	00	00
LEB 7	1	0	0	0	0	1	0	0	0	1	0	0	0	0	1

DICKS HYPOL CULCI ASPLE POLYS GRAMM UNIDE UNKNO SPH W SPH R SPH F SPH P ACRIIT BOTRY TSUGA

LWB 3	2	0	0	0	2	0	7	0	1	1	0	0	2	0	0
LWB 6	3	00	00	00	00	00	11	00	499	00	00	00	00	3	00
LWB 7	2	00	1	00	00	00	9	5	109	1	00	00	00	1	00
LSB 3	1	00	00	00	00	00	16	00	4	00	00	00	00	1	00
LSB 6	00	00	00	00	2	00	24	15	999	2	00	00	1	1	00
LSB 7	00	00	00	00	2	00	12	5	167	4	00	00	1	5	00
LMB 3	1	00	00	00	1	00	9	00	12	00	00	00	00	00	00
LMB 6	1	00	00	00	2	00	8	4	851	1	00	00	00	2	00
LMB 7	00	00	00	00	1	00	11	3	174	3	00	00	00	00	00
LMT 3	1	00	1	00	13	00	5	00	21	2	00	00	00	2	2
LMT 6	00	00	00	00	1	00	17	3	999	00	00	00	00	00	1
LMT 7	00	00	00	00	00	00	9	00	111	2	00	00	00	00	00
LEB 3	00	00	1	00	1	00	0	00	6	00	00	00	00	00	00
LEB 6	00	00	00	00	00	00	12	1	999	00	00	00	00	00	00
LEB 7	0	0	0	0	1	0	10	9	353	3	0	0	0	3	0

Table D.9

Stream Water Samples

<u>Site</u>					
Slide Code	Collection Date	Pollen Count	Pollen Concentration grains/l	Stream Flow l/sec	Pollen flux grains/sec
<u>Influx</u>					
INF 1	21 Jan.1971	144	298	180	54000
INF 2	2 July 1971	26	54	30	1600
INF 3	18 Nov.1971	13	30	1000	30000
INF 5	1 June 1972	62	128	30	3800
<u>Efflux</u>					
EFF 1	21 Jan.1971	77	292	40	11700
EFF 3	18 Nov.1971	4	9	>2000	>18000
EFF 4	20 Jan.1972	199	532	400	213000
EFF 5	2 June 1972	286	650	90	59000

Lake Surface Mud

LMD 1	Pollen count	383
	Sample fraction counted	0.0010
	Pollen concentration (grains/cc)	406151

TABLE D.9.2

		TETRA	PGALA	DODON	POMAD	HIBBE	HYPER	DRIMY	PIMEL	KUNZE	CALLI	EUCAL	ANGOP	LEPTO	EPILO	HALOR
INF	1	0	0	0	0	0	0	2	0	0	0	12	0	1	0	0
INF	2	0	0	0	0	0	0	0	0	0	0	2	0	1	0	0
INF	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
INF	5	0	0	0	0	0	0	0	0	0	0	7	0	1	0	0
EFF	1	0	0	0	0	0	0	0	0	0	0	13	0	1	0	1
EFF	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
EFF	4	0	0	8	2	0	0	0	0	0	0	41	0	8	0	2
EFF	5	0	0	0	1	0	0	0	0	1	0	159	0	0	0	1
LMD	1	0	0	0	0	0	0	2	0	2	2	60	0	5	0	3

MYRIO TIEGH HYDRO ACIPH DICHO SCHIZ EPACR EPSEK MONOT CENTA GENTI BORAG ECHIU PROST EUPHR

INF	1	0	0	1	5	1	0	2	0	0	0	0	0	0	0	0
INF	2	0	0	1	0	0	0	0	0	0	0	0	3	5	0	0
INF	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
INF	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
EFF	1	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0
EFF	3	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
EFF	4	0	0	2	4	0	0	1	0	0	0	0	0	0	0	1
EFF	5	0	1	3	2	0	1	2	0	0	0	0	0	11	0	0
LMD	1	0	0	1	10	2	3	0	0	0	0	0	0	0	0	0

PARAH GRATI UTRIC MYOPO PLANL PLANM COPRO ASPER WAHLE STYLI TUB 1 TUB 2 TUB 3 TUB 4 TUB 5

INF	1	0	0	0	0	0	1	0	0	0	0	2	10	2	2	0
INF	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
INF	3	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
INF	5	0	0	0	0	4	0	0	0	0	0	1	4	3	1	0
EFF	1	0	0	1	0	0	0	0	0	0	0	2	5	4	0	0
EFF	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
EFF	4	0	0	1	0	1	4	0	0	0	0	5	15	4	1	0
EFF	5	0	0	0	0	0	0	0	0	0	0	3	2	3	1	0
LMD	1	0	0	0	0	0	0	3	0	0	0	13	21	25	4	3

TABLE D.9.3

		LIGU	EWART	PODOC	DACRY	CUPRE	PINUS	LYCSE	LYCFA	OPHIO	FILIM	FILIT	F 137	F 156	PELLE	CHEIL
INF	1	0	0	0	0	0	5	1	0	0	0	0	0	0	0	0
INF	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
INF	3	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0
INF	5	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0
EFF	1	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0
EFF	3	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
EFF	4	1	0	0	0	1	3	0	0	0	3	0	0	0	0	0
EFF	5	1	0	0	0	0	0	0	0	1	2	0	0	0	0	0
LMD	1	0	0	0	0	2	1	0	0	0	7	4	0	0	0	2

		DICKS	HYPOL	CULCI	ASPLE	POLYS	GRAMM	UNIDE	UNKNO	SPH W	SPH R	SPH F	SPH P	ACRIT	BOTRY	TSUGA
INF	1	0	0	0	0	0	0	15	13	0	0	0	0	0	0	0
INF	2	0	0	0	0	0	0	3	2	0	0	0	0	0	0	0
INF	3	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
INF	5	0	0	0	0	0	0	1	10	0	0	0	0	0	1	0
EFF	1	0	0	0	0	1	0	0	3	3	0	0	0	0	0	0
EFF	3	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
EFF	4	0	0	0	0	0	0	5	10	157	0	0	0	0	1	0
EFF	5	1	0	0	0	2	0	10	8	20	0	0	0	0	1	0
LMD	1	0	0	1	0	0	0	30	3	195	4	0	0	0	2	0

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